PC CONTROLLED RF & DC MAGNETRON SPUTTERING SYSTEM

SYSTEM MANUAL

MODEL NO: MAGSPUT-4G4-RF-DC-1G2-DC-PC

SERIAL NO: MSS-4G4-RF-DC-1G2-DC-NANOTECH-080912-MJD5-MS

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Thin Film & Nanotechnology

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1 Torr = 1 mm Hg

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INTRODUCTION

The PC controlled RF and DC Magnetron sputtering series Thin Film Sputtering System is created to customize specifications in order to allow great flexibility in the sputtering process. Every effort has been made to produce a system of outstanding capability in a compact and easy to use format; nonetheless, please make sure that the operator reads the system manual, Help file and pays particular attention to the maintenance and operation sections. The operator should also read and familiarize himself with all of the system component manuals and THIN FILM SPUTTERING PROCESS manual on operation. Failure to follow the guidelines set forth in this manual can invalidate any warranties this equipment may be under, and may result in a degradation of system performance.

SUB-SYSTEM OVERVIEW

The PC Controlled Magnetron Sputtering System consists of highly polished large stainless steel D shaped water cooled vacuum chamber with a vacuum system using Turbo V-1001 l/sec capacity turbo pump with a water cooling water lines and a matching double stage rotary pump for sputtering system (DS-302) and TV-81 l/sec turbo pump with matching mechanical pump for load lock chamber (SL-250). Two 4” dia. viewports are dedicated on the chamber door in order to see the process clearly and one 2” dia. on right side of the chamber wall to monitor process during sputtering operation. The sputtering system is equipped with baratron capacitance manometer gauge (MKS 626B) and full range cold cathode pirani gauge (PKR 251) to measure the vacuum throughout the process in main chamber. The load lock is installed with full range cold cathode pirani gauge (PKR 251) to measure the vacuum in load lock during process. The system is integrated with smart star SL-200 automated load lock, designed to transfer 200mm sample in/out from chamber. The load lock has transfer valve, separate pumping station which includes turbo pump and a backing pump, vacuum gauge, vent valve and a safety interlock with a magnetic coded safety switch (Lid closed).

The sputtering system has two separate substrate stage within process chamber. First substrate stage of 8” in diameter and can hold multiple samples within a size of 7” including rotation up to 20 rpm to achieve better uniformity and is able to provide heating to the substrate stage up to 400 ° C using backside IR type quartz lamp heating arrangement. The second substrate stage is of 2.5” in diameter and is isolated from another stage and it can hold custom size sample within 2” dia. To achieve better uniformity, the stage is installed with IR type quartz lamp heating

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arrangement to achieve 800 ° C temperature. The system is installed with four 4” flex type IC Magnetron Sputtering sources with motorized shutter assembly and one 2” standard straight type IC Magnetron Sputtering source with motorized shutter assembly. The sputtering sources includes three 4” standard type flexible IC magnetron sputtering guns for DC magnetron sputtering and one 4” magnetic type flexible IC magnetron sputtering guns for RF magnetron sputtering process.

The sputtering system has three mass flow controllers with shut off valves for process gases are provided. The sputtering system consists of three DC power supplies and one RF power supply. The system incorporates one 1000 Watt RF power supply (13.56MHz) with Auto Matching network and matching network controller to minimize the reflected power to about or less than 1% of the forward power. Also one 600 Watt, 1000Volt DC power supply is interfaced with PC control software. The system also integrated with two of 2000 Watt DC power supplies and are interconnected through a switch box dedicated to just two of the 4” magnetron sputtering sources. Each power supply is dedicated for two sputtering source. The water cooled dual quartz crystal thickness sensor is interfaced with PC to monitor thickness during sputtering process. The system comes with RF cleaning capability. In RF cleaning process, plasma of excited and Argon ions attracted to the substrate stage are used for the removal of mostly organic materials and thin native oxide layers on the targets. The system is a perfect example of automation deposition process using dedicated PC control software and necessary hardware. All power supplies, safety interlocks and water interlocks are tied to PLC and PC control system software to achieve fine process control.

The PC controlled Magnetron Sputtering System is also incorporated with soft wall clean room. It is compact, modular design and ISO class 5 with 5.8” X 10” X 7” dimensions which uses 5 HEPA filter fan units with built in internal lights, constructed of power coated steel panels with vinyl curtains and casters. Isocide antimicrobial coating on all painted surfaces minimizes contamination. This version is an extendable modular design and can be expanded if research space needs to be increases.

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SYSTEM UTILITIES REQUIRED

- **SPUTTERING SYSTEM UTILITIES:**
  - 240V, 50Hz, 40 Amp. and Single Phase
  - Cooling water at 2 gal/min (7.57 liter/min), 20-24ºC, with 3/8" Pisco fittings
  - Compressed air at 5-7 bar (72.51-101.52 PSI) (4.93-6.90 Atm).
  - Process gases like Ar at 1.10 bar (16 PSI) (1.08 Atm).
  - Dry N_2 for venting at 1-1.2 bar (14.50-17.40 PSI) (0.98-1.18 Atm).

- **SOFT WALL CLEAN ROOM (CR, SOFTCAPSULE, SC-8107-M3):**
  - 230V, 50Hz, Single Phase & 1.36Kw Power Consumption

- **WATER CHILLER (OC-25R) UTILITIES:**
  - 230V,50Hz, 15Amp & single phase
  - Standard Pump Capacity for Cooling water: 1.6GPM (Only use distilled water)
  - Tank capacity: 2 Gallon (7.5 Litter)
  - 2500 BTU/hr

- **WATER CHILLER (OC-75R) UTILITIES:**
  - 230V,50Hz, 15Amp & single phase
  - Standard Pump Capacity for Cooling water 4 GPM (Only use distilled water)
  - Tank capacity: 4 Gallon (15 Litter)
  - 8000 BTU/hr

NOTE: Please keep in mind that the supply voltage must be within 10% of specified voltage. The water chiller should be plugged into 15Amp circuit breaker using 6" power cord provided with the system. We strongly recommend reading OEM's manual prior to start the system.

NOTE: A mixture of 30% ethylene glycol and 70% distilled water is suggested. DO NOT USE AUTOMOTIVE ANTI FREEZE AS COOLANT.

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FRONT PANEL CABINET FOR MAGSPUT SYSTEM

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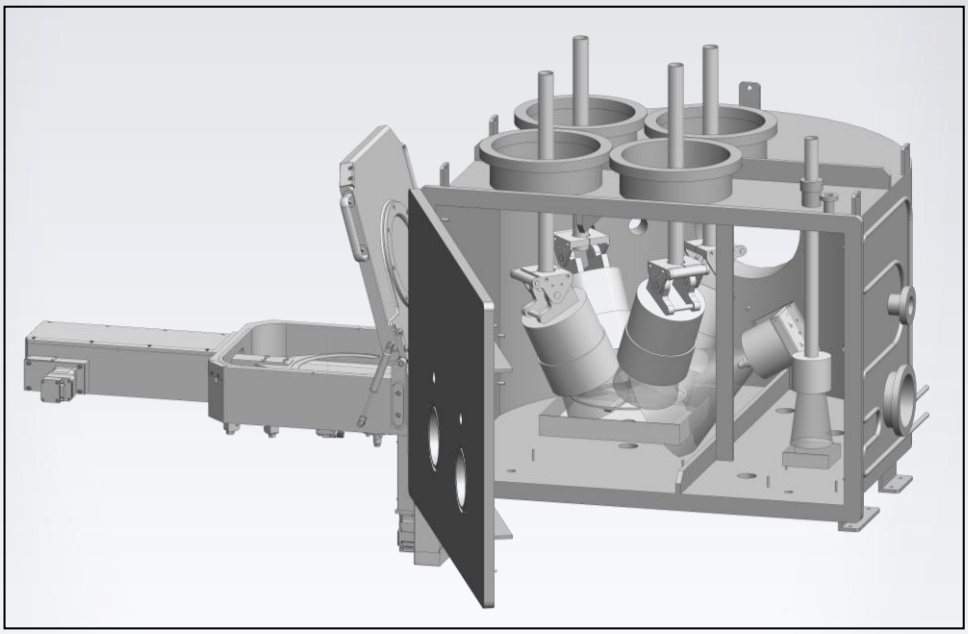
SYSTEM COMPONENTS

- **PROCESS CHAMBER:**
  The vacuum process chamber is made up of highly electro polished 304L stainless steel and features two view ports on the front door. The fully opening front door is convenient for changing targets, substrate holder and all other accessories like thickness sensor, thermocouple, gas inlets as well as easy chamber cleaning and maintenance. The chamber dimensions are 28” Height x 28” Width x 28” Depth. The base plate contains the rotatable substrate stage with Infrared IR type quartz lamp heater. The top plate contains four 4” magnetron sputtering guns with necessary water cooling lines and shutter and one 2” sputter gun with motorized shutter. The chamber has fully flanged ports for Turbo Pump, vacuum gauge, vent valve, gas inlets and two thickness sensor etc. Chamber has few additional ports for future use.



3D LAYOUT OF THE SPUTTERING SYSTEM WITH LOAD LOCK INTEGRATION

- **VACUUM SYSTEM:**
  The vacuum system is consist of two sets of turbo pump, dedicated to process chamber and load lock. For the size of the process chamber which is incorporating five magnetron

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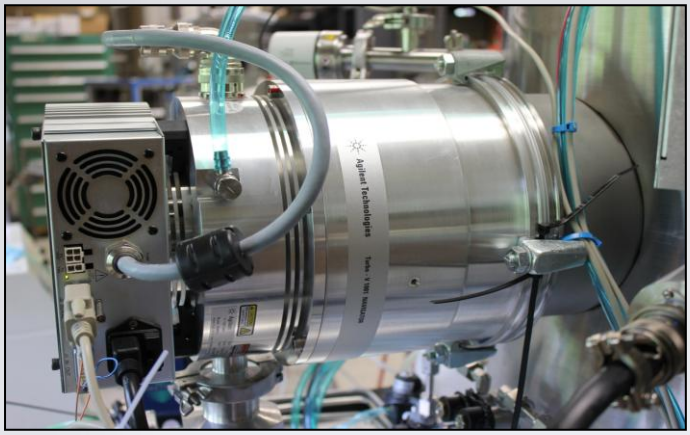
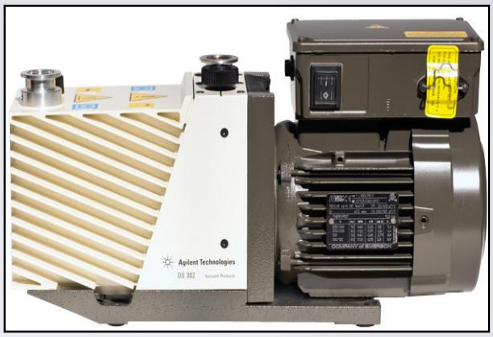
sputtering system, a turbo pump of TV1001 l/sec capacity turbo pump with a water cooling water lines and a matching (DS-302) double stage rotary pump. For load lock system a turbo pump TV81M with controller is used to achieve desired vacuum during the process and is backed by dry scroll (SV2211) mechanical pump. A full range vacuum gauge measures from 760 Torr to 10^{-9} Torr and can be viewed on TORR-NANOTECH multi tool THIN FILM software in computer. An operating vacuum can be achieved in around forty minutes in a clean room environment. The majority of vacuum seals are of conflate type with OFHC copper gaskets to help ensure the level of vacuum desired.



TV 551 TURBO PUMP WITH CONTROLLER



DS302 MECHNICAL PUMP

TV 81M TURBO PUMP WITH CONTROLLER

ISP90 MECHNICAL PUMP

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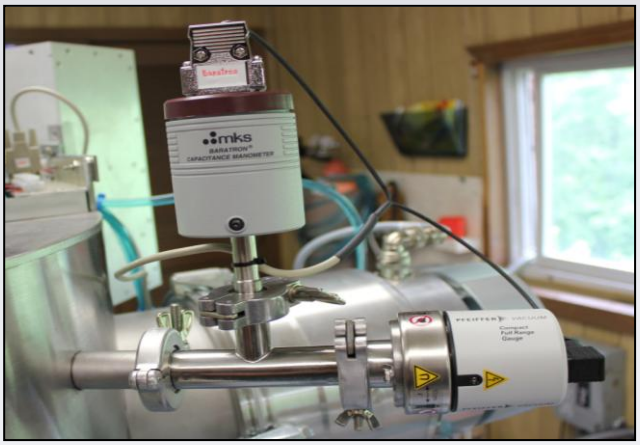
- **VACUUM PRESSURE MONITORING:**
  The system comes installed with two vacuum pressure gauges for monitoring chamber pressure. The first vacuum gauge is a baratron (MKS 626B) capacitance manometer. The second gauge is a combination full range gauge, cold cathode and pirani gauge (Pfeiffer PKR251). A capacitance manometer is used to increase the speed and accuracy within process levels while cold cathode pirani gauge is used for wide vacuum range. The capacitance manometer gauge can measure vacuum levels from 1 Torr to 10^{-4} Torr. The full range gauge can measure vacuum levels from 760 Torr to 10^{-9} Torr. The load lock system is equipped with the combination full range gauge, cold cathode and pirani gauge (Pfeiffer PKR251) to measure the vacuum levels from 760 Torr to 10^{-9} Torr.



626B CAPACITANCE GAUGE & FULL RANGE PKR251 GAUGE

FULL RANGE PKR251 GAUGE

NOTE: When in the active range of the capacitance manometer, the computer reads and functions off the capacitance gauge. It will monitor the sputtering deposition process within this range.

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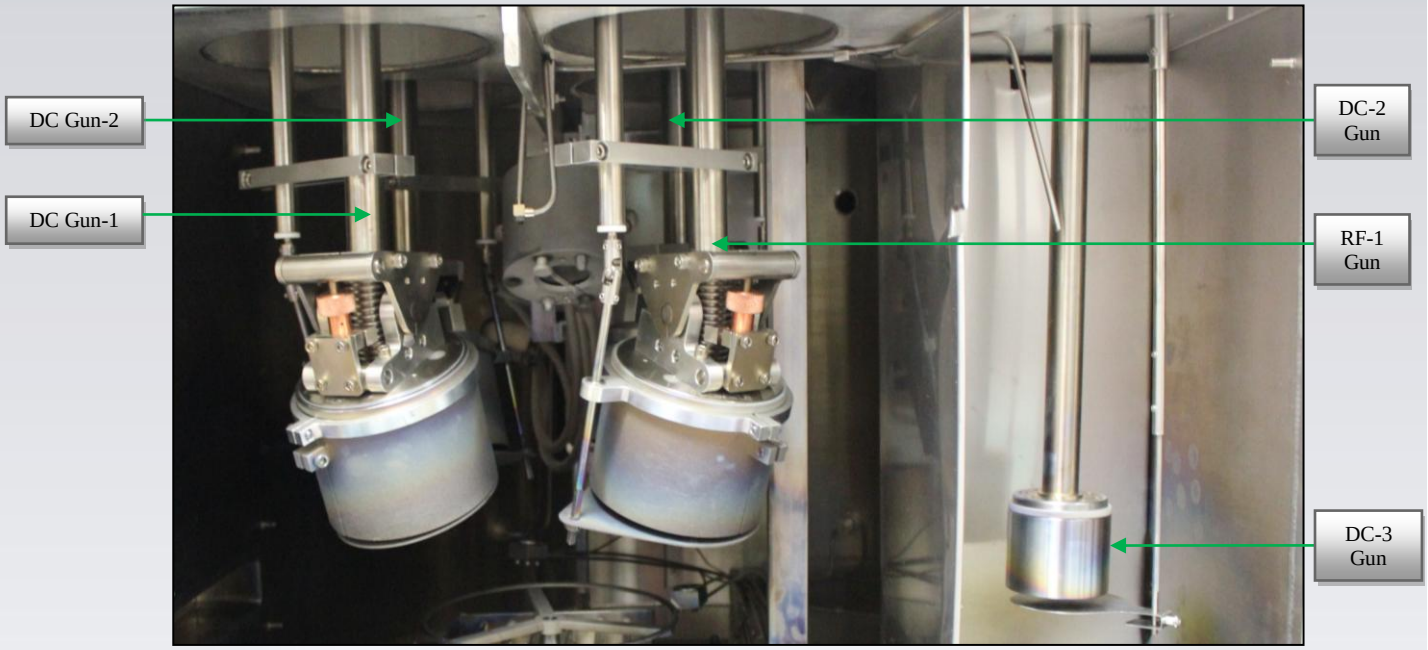
- **PLANAR MAGNETRON SOURCES (4X4" & 1X2" SPUTTER GUNS)**
  The planar magnetron deposition sources, sometimes referred to as the sputtering guns, are Four Guns with four inch diameter, water cooled sources and one 2" sputtering gun with motorized shutter assembly. This deposition sources utilize an innovative Torr International programmed shutter assembly and is also manually retractable while maintaining a focal point directly on the center of the substrate stage. Please refer to OEM manual for further technical information on the magnetron sources.



FOUR 4" FLEX TYPE MANGETRON SPUTTERING GUNS & ONE 2" STANDARD STRAIGHT TYPE SPUTTERING GUN

- **SOURCE POWER SUPPLY MODULES:**
  This magnetron sputtering sub-system has three DC power sources and a RF power source for sample processing. The two High Voltage DC power supplies are capable of producing up to 2000 volts to a given source, and are ideal for use in sputtering conductive elements. One 600 Watt DC power supply is incorporated with the system for dedicated sputtering gun. Dielectric materials and compounds such as Silicon can be sputtered using the 1000W (13.56MHz) RF power supply. The RF supply has an automatic matching network with a dedicated controller to minimize the reflected power is about or less than 1% of the forward power during operation. Both the total and reflected power can be seen on digital display on the front panel on PC control software.

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- R1001 RF POWER SUPPLY WITH MC-2 AUTOMATCHING CONTROLLER
- 600 WATT DC-3 POWER SUPPLY
- K&R CONTROLLER with FILAMENT CONTROLLER & DISCHARGE CONTROLLER
- 2000 WATT DC-1, DC-2 POWER SUPPLY

The sputtering system is also incorporates gridless end hall source from Kaufman & Robinson. The gun will normally operate with Argon flow controller which it is installed with system and is of 50 SCCM. Please refer to individual component manuals for more detailed information. The system is included with filament controller and discharge controller.

Please refer to each of the power supplies' OEM manual for further technical information.

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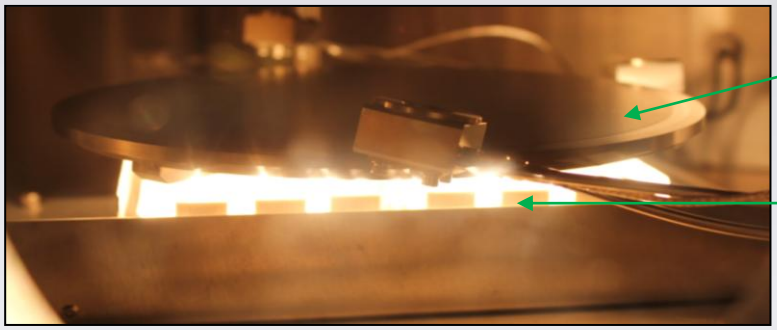
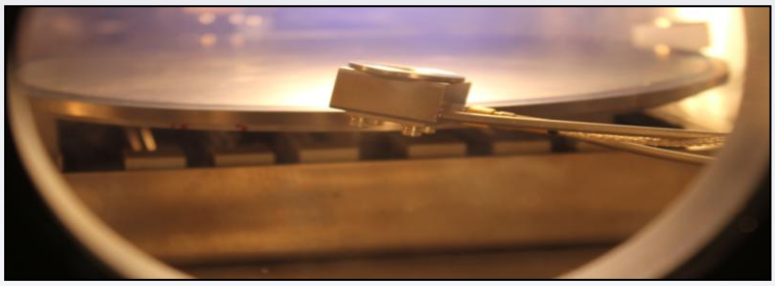
- **SUBSTRATE STAGES with HEATER AND ROTATION:**
  There are two substrate stage installed in the process chamber. The first sample stage is made from Titanium alloy, circular in shape and is capable of holding up to 8" dia.(220mm) or smaller size samples. Convenient threaded holes and springs will be used to hold any round or irregular shape samples against the substrate holder. To help ensure more uniform deposition the substrate stage can be heated up to 400° C temperature using IR quartz lamp heater and rotated. Substrate Rotation from 0-20 rpm is available and adjustable for 3% uniformity. The substrate stage is installed with motorized shutter assembly which is controlled using Torr Tool Control software during the sputtering process.





SUBSTRATE STAGE WITH 20RPM ROTATION & 400° C HEATER ARANGEMENT

Another substrate stage is also made of titanium alloy, circular in shape (approximately 60mm dia.) This can hold a single 50mm or smaller wafer, or multiple samples/wafers within the range of 50mm dia. This secondary stage has spring clips and threaded holes to hold any kind of shape samples.

Note: It is necessary to check that IR lamps are positioned properly when a maintenance service is performed.

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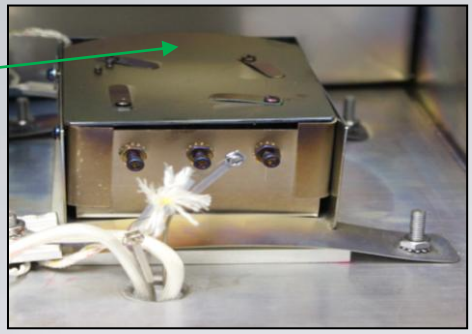
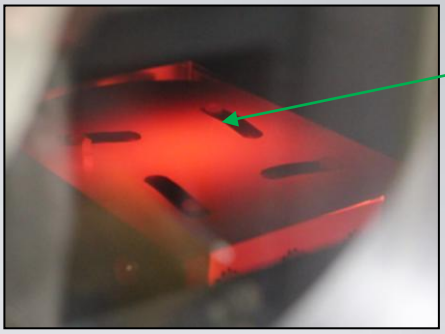
Substrate Stage of 60mm dia. & Heater up to 800° C

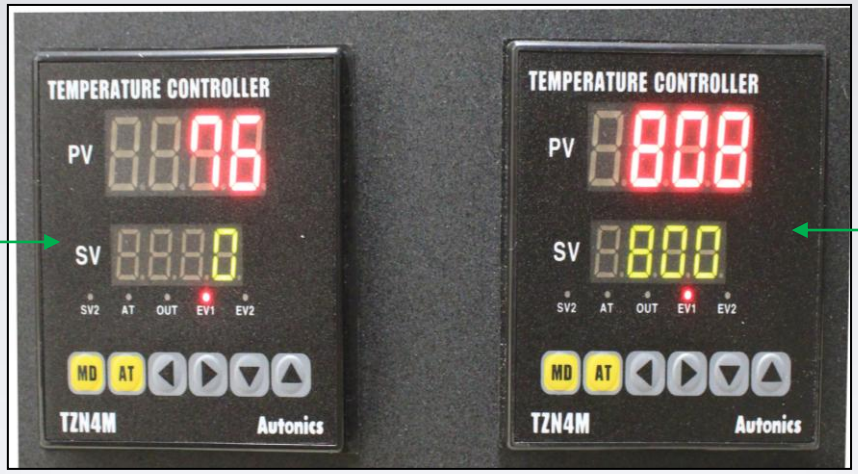




Substrate Stage with Spring Clips

SUBSTRATE STAGE WITH 800° C HEATING

Temp. Controller-1 up to 400° C



Temp. Controller-2 up to 800° C

SUBSTRATE STAGE TEMPERATURE CONTROLLER

NOTE: The Heater Controller can achieve up to 700° C temperature using a PID temperature controller, which monitors type K thermocouple placed on the edge of the IR heater's reflector as a comparable reference to the substrate stage. We strongly recommend to follow two steps to achieve 700° C . Initially set the temperature up to 450° C and wait to stabilize temperature at substrate stage. After some time the user can increase the temperature up to 700° C as per requirement. We do not recommend to run the heater at 700° C for more than 30 minutes. It can damage the sputtering guns and target. The user can run the heater at about 600° C without any problem for long period of time.

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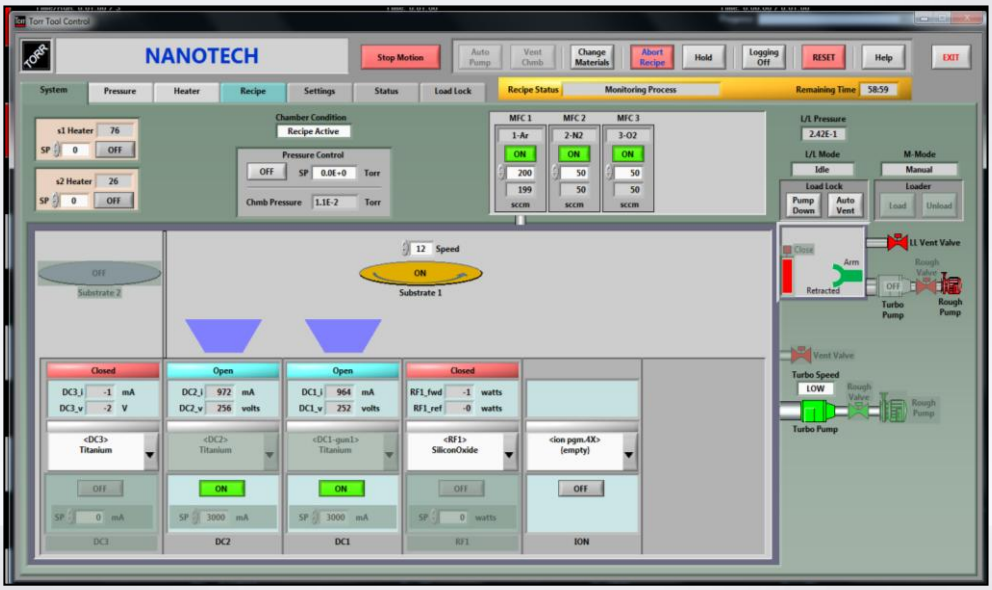
- **PROCESS – SYSTEM CONTROL VIA PC:**
  This unit is entirely operated through a dedicated PC with preinstalled Torr designed software based on Lab View platform for Graphical User Interface, popular in automation process. Thin Film Deposition Control software controls the vacuum process, all sputtering process and also can collect the data and stores them in PC. There is another version of software cum controller (SQS-242 CoDep) installed in computer for recording deposition rate while running the recipe. This controller uses dual quartz crystal thickness sensors, oscillator and cables to not only measure film thickness and deposition rates but controls system power and rates of deposit (tied directly to the power supplies in order to provide automatic and semi-automatic deposition process). Computer control is done through the system with an embedded Programmable Logic Controller (Monitoring & Maintaining all process related safety interlocks digitally).



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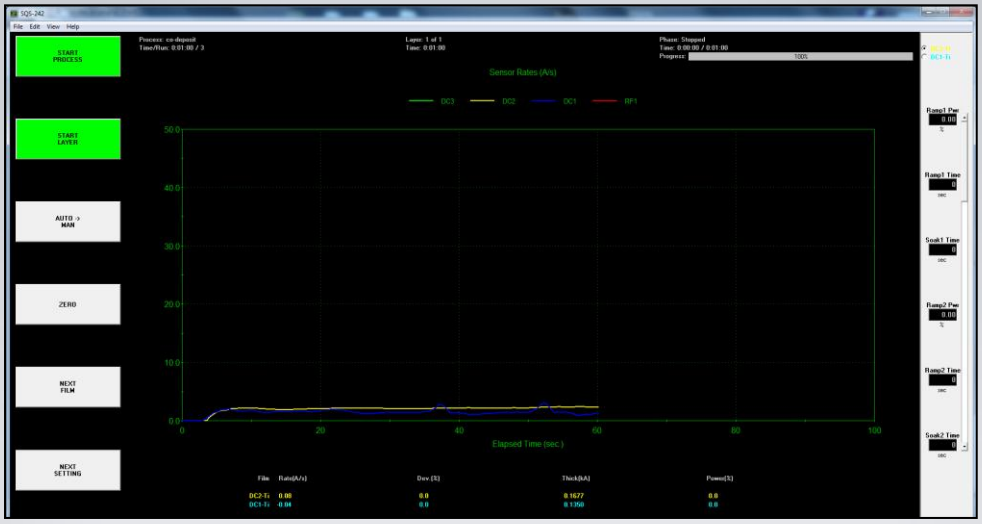

THIN FILM DEPOSITION CONTROLLER SOFTWARE

Thickness Sensor: The installed crystal sensor uses the impendence of the oscillation frequency on the mass of your crystal oscillator to determine the thickness created during a given deposition process. As mass increases by any factor, the frequency will decrease by square root of the inverse of that factor. The FTM-2000 re-zeroes itself before each process

to utilize relative changes in mass, allowing for numerous deposition processes before changing the quartz sensor. The **Density** of the material is measured by the quartz crystal sensor in grams per cubic centimeter (gm/cc). **Z-Factor** compensates for the mechanical stress a material causes to the quartz crystal. **Tooling factor** is for compensation of measured deposition rates that differ from the actual substrate deposition rate based upon relative distance and position of the crystal sensor when compared to position of substrate stage. The tooling factor must be fine tuned for each crystal sensor at the end user's facility upon successful installation of the system and anything with the position of the crystal sensor.. Example: If the sensor sees only 50% of the substrate rate, set the value to 200. This will multiply the sensor reading by 2.

NOTE: You can check the life of crystal by simply checking "Sensor Readings" in the FTM 2000. If it shows life less than 30% then change crystal right away. After using a crystal for a long time, you should change the crystal by simply removing the crystal from the sensor assembly and carefully replacing it with the new crystal.

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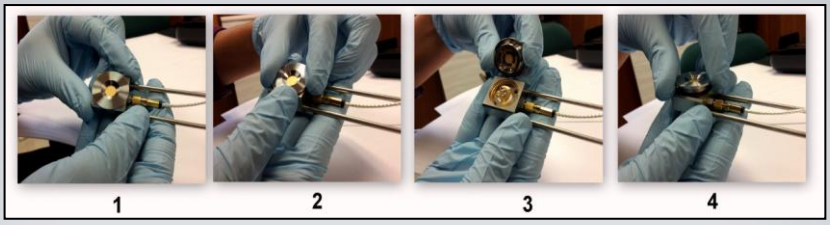
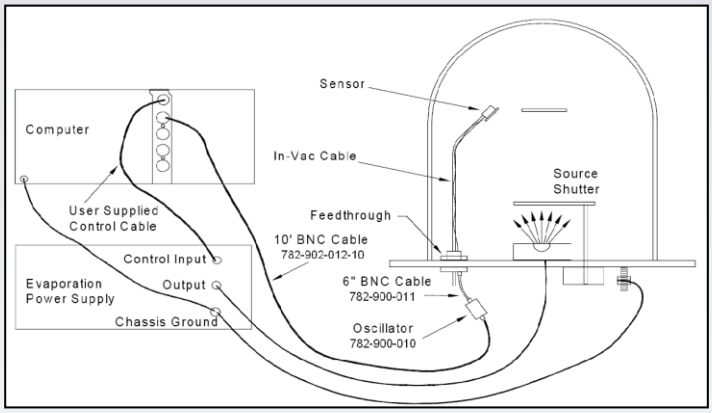


CRYSTAL SENSOR ASSEMBLY



Courtesy: INFICON Product catalog

Readings

	Rate (A/s)	Thick (kA)	Freq. (Hz)	Life (%)	Source
Sensor 1	.0	0.000	5950000.0	95.0	Output 1
Sensor 2	.0	0.000	5950000.0	95.0	Output 2
Sensor 3	Not	Used	5950000.0	95.0	None
Sensor 4	Not	Used	5950000.0	95.0	None
Sensor 5	Not	Used	5950000.0	95.0	None
Sensor 6	Not	Used	5950000.0	95.0	None
Sensor 7	Not	Used	5950000.0	95.0	None
Sensor 8	Not	Used	5950000.0	95.0	None

	Units	Volts	Control
Analog 1	0.0	.00	Not Used
Analog 2	0.0	.00	Not Used
Analog 3	0.0	.00	Not Used
Analog 4	0.0	.00	Not Used

CRYSTAL SENSOR LIFE CHECK LIST

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APPENDIX-THE CRYSTAL THICKNESS SENSOR THEORY

THEORY OF OPERATION

The sensing device of the thickness monitor is a quartz crystal oscillator which is externally excited into vibration in the thickness shear mode at a nominal frequency of about 6 MHz. The frequency of this vibration is affected by the material deposited on the surface of the crystal by the material deposited on the surface of the crystal by the planar magnetron guns. The crystal responds in an inverse fashion, that is higher levels of deposits result in lower frequencies.
Below is the most common current equation in measurement theory:

$$T_f = (D_q/D_f) * (N_q TZ/\Pi) * [\text{atan}\,(z^{-1} * \tan(\pi\,(1-T_q/T)))\,]$$

Where,

T_f = Thickness of film in centimeters
D_q = Density of quartz (g/cm^3)
D_f = Density of the film (g/cm^3)
N_q = Frequency constant of crystal (Hz/cm)
T = Period of the loaded crystal
Z = Z ratio of the film (Acoustic Impedance Ratio)
π = 3.1416
T_q = Period of unloaded crystal

NOTE: The values given in the program for the Z ratio and density of materials are bulk values. True thin film densities and acoustic impedances of materials varies with the deposition conditions and substrate temperature. We recommend to calibrate Thin Film Density prior to process. The acoustic impedance ration only becomes relevant for heavily loaded crystals, and bulk values given will yield approximately correct results and need only be changed for very exact measurements.

1. CALIBRATION

The following procedure is recommended for determining Density, Tooling Factor and Z ratio for unknown materials:

- Density Calibration:
  - Using the OTHER selection in the target window, select the bulk or estimated
  - value of the density of the material. Select a Z ratio of 1.0 and a tooling factor of 1.0 (If the correct values for Z ratio and tooling are already known, use those instead)
  - Make a trail deposit onto a New crystal with several test substrates placed as close to the crystal (but not masked by it) as possible. Make a thin coating (500 to 1000 angstroms) and measure the actual thickness on the test substrates.

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- Determine the density from the following equation.

$$D_a = D_e * (T_i/T_a)$$

Where,

D_a = Actual density of the material
D_e = Estimated density of the material
T_i = Thickness indicated by the ARC
T_a = Actual measured thickness of the material

- Tooling Factor:
  - Use the known density and Z ratio for a material. Place several test substrates on the sample stage and make a thin coating (500 to 1000 angstroms). Measure the actual thickness of the material on the substrates and the indicated thickness on the screen.

The tooling factor = T_a/T_i

NOTE: This calibration procedure must be done separately for each gun. Also tooling is dependent on the distance horizontally of the crystal from the center of the plasma; therefore moving the crystal on the swinging arm will change the tooling factor.

- Z Ratio:
  - This is the final step in the calibration of the thickness monitor and is frequently unnecessary. Usually, assuming a value of 1.0 for the Z ratio is adequate for measurement accuracy. In order to calculate the Z ratio of a material from a known acoustic impedance, plug the values into the following equation:

$$Z = Z_m/Z_q$$

Where,

Z = Z ratio
Zm = Acoustic Impedance of material (* 10^5g/cm^{2}s)
Zq = Acoustic Impedance of quartz (8.834 * 10^5g/cm^{2}s)

To calculate the actual Z ratio of a material , the density and tooling factor must be known. Set the Z ratio to 1.0 Deposit material on a fresh crystal until it ceases to oscillate. Note the thickness and coat a new crystal to 80% of that values. Place a substrate on the stage and make a thin deposition. Measure the correct thickness of the deposition, and substitute the value for Z into the equation (It is recommended to use a program to solve this equation) that will cause the indicated thickness to equal the measured thickness. The thickness monitor is now ready to produce consistent monitoring information.

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INSTALLATION & SETUP

The information in this manual is for your reference only. Before operating any component of the Torr International Inc. System, you must first review the manual for each individual component, and always follow the manufacturer's instructions. For complete individual component specifications & operational details, refer to the OEM's manual for each component that was provided with the Torr International Inc. System upon delivery.

INITIAL SETUP

Open all shipping containers and inspect the unit and accessories for damage. In the event that damage did occur, please contact Torr International, Inc. and the representative freight carrier immediately. Please follow the steps listed below.

Open the shipping crates & boxes and take out the shipped components. You should find the following items:

1. One PC Controlled RF and DC Magnetron Sputtering series Thin Film System Cabinet with Stainless Steel Chamber attached.
2. One Mechanical Pump (DS-302 & ISP-90) & A Closed loop Water Chiller (OC-25R & OC-75R) system.
3. Soft wall clean room and load lock SL-200.
4. Instruction Manuals & Discs: These are originals, make copies for multiple users.

NOTE: If you do not find one or more of these items, please contact Torr International, Inc.

Place the PC Controlled RF/DC Magnetron Sputtering System unit at prepared laboratory location and near to system utilities in environmental controlled laboratory.

TWO STAGE ROTARY MECHANICAL PUMP

IMPORTANT: DO NOT ATTEMPT TO RUN THE TWO STAGE ROTARY MECHANICAL PUMP IN ATMOSPHERIC AGENTS. (See Two Stage Rotary Mechanical Pump instruction manual for directions). It is very important that you check your electrical mains. Connect the pump to electrical outlet using an IEC-320 style power cord. The outlet is located on the system utility panel on the rear of the system cabinet.

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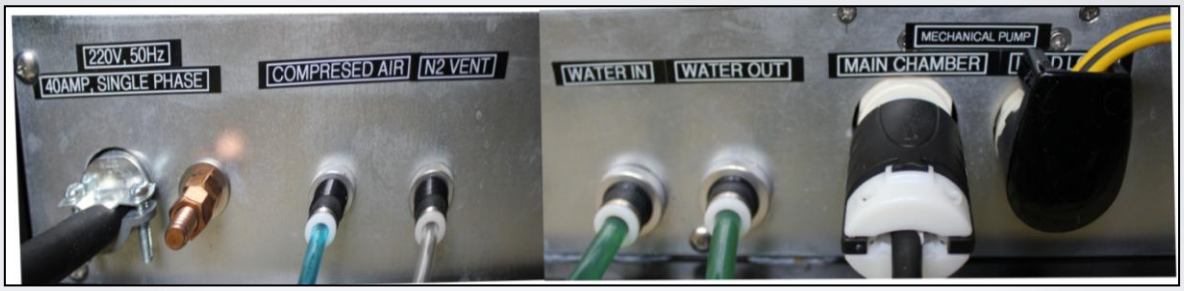
VACUUM HOSE - Connect the vacuum hose that originates from the back of the Magnetron Sputtering system cabinet to the two stage rotary mechanical pump using the provided vacuum hose and KF-25 fittings.

Note: Please read OEM's Manual for detailed set up process and proper maintenance schedule and procedure for The Mechanical Rotary Pump.

DUAL STAGE ROTARY VANE VACUUM PUMP

VACUUM HOSE CONNECTION

MECHNICAL PUMP for LOAD LOCK



BACK UTILITY PANEL FOR SPUTTERING SYSTEM

POWER CONNECTION - Plug the mechanical pump's power cable into the designated electrical outlet on the back panel of the PC controlled RF/DC Magnetron Sputtering series thin film deposition system and make sure to double check electrical utilities prior to system startup. It is clearly marked as "MECHANICAL PUMP" for process chamber and load lock. Please do not mismatch the connections. The outlet for each mechanical pump is marked clearly.

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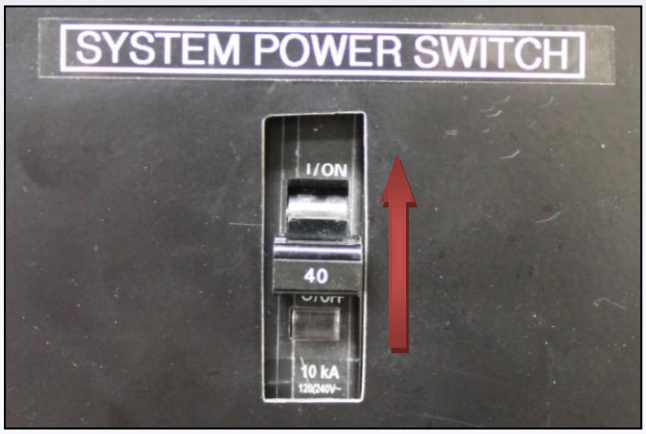
NOTE: This outlet is for the mechanical pump only. Do not attempt to modify or switch the plug to another component.

ELECTRICAL CONNECTIONS:

The system operates on 240V, 50Hz, 40Amp and single phase power connection. The required voltage is clearly marked on the back of the system cabinet where the AC input power cable originates. On the rear side of the system cabinet, be sure the main power switch is set to OFF position, and then plug the AC power cable into a properly grounded electrical outlet.



PUSH BREAKER IN UPWARDS DIRECTION TO TURN THE SYSTEM ON

MAIN SYSTEM BREAKER

NOTE: The unit is grounded through the main power cable and also use RF generator ground for an independent earth ground. Be sure to ground the system using this connection. It is very important that the system is grounded properly before the start of the system. We recommend that all the electrical services should be done by an qualified electrician only at the end user's site.

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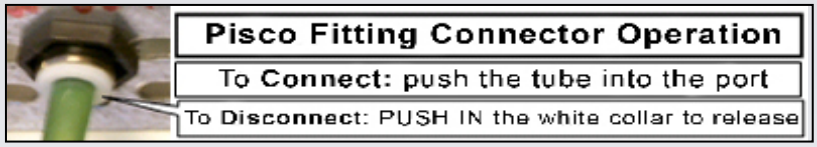
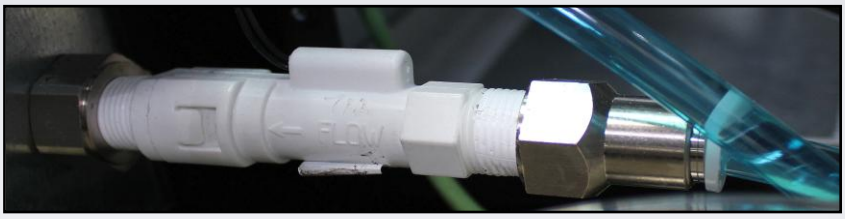
WATER CONNECTIONS:

The Magnetron Sputtering System is properly water cooled in order to increase operational life of the system. You must provide cooling water with a flow rate of at least a 2 liter/minute at 4.5-5 Atm and at approximately ambient room temperature for turbo pump and two magnetron guns. Also, as an added measure of safety, the power supplies will experience a fault condition and will not operate unless the coolant water is flowing. Condensation can dramatically shorten the life of your system and can cause system failure. Please maintain Laboratory conditions in order to achieve better performance. A closed loop water chiller is provided for this system. Follow OEM specification properly. Be preparing to use only distilled water in this chiller.





NOTE: FOLLOW "WATER IN" & "WATER OUT" FITTINGS. DO NOT RUN THE SYSTEM WITHOUT THE COOLING WATER FLOWING. WE RECOMMAND USING AN INDUSTRIAL CLOSED LOOP, WATER CHILLER. CONTACT TORR INTERNATIONAL INC. FOR FURTHER INFORMATION.

CLOSED LOOP WATER CHILLERS (OC-25R & OC-75R)

This OC-25R & OC-75R water chiller is designed to provide a continuous supply of clean water based coolant to the process. It is a completely self contained unit consisting of reservoir, recirculation pump and air cooled refrigeration system.

Make vacuum hose connections to the ½" FPT fittings on the rear panel tagged DISCHARGE and RETURN. Please verify the level of distilled water prior to the operation. Once the cooler has been filled with coolant and the proper plumbing and electrical connections have been made, it can be started by pushing the ON/OFF switch on the front panel to the ON position. An internal light will energize and pump will start and run continuously.

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- **WATER CHILLER (OC-25R) UTILITIES:**
  - 230V,50Hz, 15Amp & single phase
  - Standard Pump Capacity for Cooling water: 1.6GPM (Only use distilled water) and factory set pressure limit is 60 psi
  - Tank capacity: 2 Gallon (7.5 Litter) & 2500 BTU/hr

- **WATER CHILLER (OC-75R) UTILITIES:**
  - 230V,50Hz, 15Amp & single phase
  - Standard Pump Capacity for Cooling water 4 GPM (Only use distilled water)
  - Tank capacity: 4 Gallon (15 Litter)
  - 8000 BTU/hr

NOTE: Please keep in mind that the supply voltage must be within 10% of specified voltage. The water chiller should be plugged into 15Amp circuit breaker using 6" power cord provided with the system. We strongly recommend reading component's OEM manual prior to start the system.

NOTE: A mixture of 30% ethylene glycol and 70% distilled water is suggested. DO NOT USE AUTOMOTIVE ANTI FREEZE AS COOLANT.

GAS CONNECTIONS:

1. **Compressed Air:** Connect compressed air to the ¼ inch Pisco fittings on the rear of the unit. The source pressure should be at 75 PSI (5.10 Atm Pr).

2. **Nitrogen (for venting):** - Connect a laboratory graded Dry Nitrogen gas supply through a two stage regulator to the ¼" Pisco fitting on the labeled "VENT" at the rear of the CRC-622. The source pressure should be 1 kg/cm^2 (14-20 psi). This is for venting the chamber.

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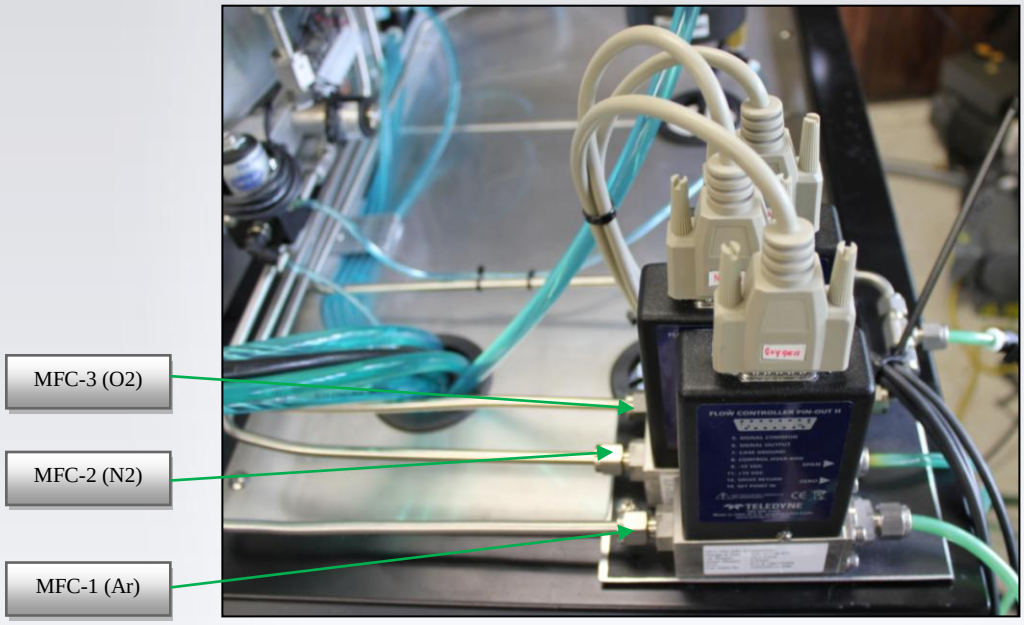
3. **Process Gases (Ar,N_2 & O_2):** The process gases like Argon, Oxygen and other gases are needed for many of your deposition processes at the pressure of at 16 PSI (1.08 Atm Pr). Connect them to the top rear panel on your system cabinet using ¼" Pisco fittings only**.**

- **GAS DELIEVERY SYSTEM:**

The unit comes with two mass flow controllers calibrated for 200 SCCM gas flow rate for nitrogen and oxygen gases, with isolated shutoff valves and one mass flow controller, calibrated for 600 SCCM flow rate dedicated for argon gas.

Note: A Laboratory graded Dry Nitrogen gas is used for venting as well as vacuum purging cycles. The Nitrogen gas line does not use MFC. **Below is a set up for Oxygen gas flow connection for MAGSPUT system.**



MASS FLOW CONTROLLER SET UP FOR AR,N2 & O2

MAGNETRON SPUTTERING SYSTEM POWER UP

Once all necessary connections are complete, turn on the power to the system using the Main Power switch on the side of the system cabinet. Each component in the system cabinet also has its own individual power switch. Check that all of the components have power. The Sputtering System is then ready for operation.

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NOTE: If the system will not power up, check your power outlet's main breaker. If it will still not power up, contact Torr International, Inc. for further assistance.

SPUTTERING RATES & DEPOSITION RATES

The sputtering rate is the rate that material leaves the sputtering target. The film deposition rate is the rate that sputtered material condenses on the substrate. The deposition rate is less than the sputtering rate because some of the sputtered atoms are scattered in random directions by the sputtering gases and do not reach the substrate.

SPUTTERING RATES

The sputtering rate depends on:

- The flux of ions bombarding the target-the ion current density (ions/cm^3).
- The sputter yield-the number of atoms that leave the surface per incoming ion (atoms/ion)
- Heat of vaporization of the target material-which depends on the material and surface crystal structure.
- Ratio of the ion mass to atomic mass of the target
- Ion energy (Voltage on the target)
- Angle at which the bombarding ion strike the target

DEPOSTION RATES

The growth rate of the deposited film depends on the geometry of the deposition system and the efficiency of transfer of atoms from the target to the substrate. The geometric factors are the target-substrate distance and the ratio of the target area to the target-substrate spacing. For an amorphous or polycrystalline target, the material leaves the target with an approximate consine density distribution and the deposition rate decreases with the square of the distance-just as in evaporation.

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THEORY OF PLANNER MAGNETRON SPUTTERING

In order to make the most effective use of this Thin Film Deposition System, it is necessary to understand some of the basic parameters involved in creating thin films using a planar magnetron source.

A uniform film of high purity cannot be achieved unless the chamber is first cleared of excess atmospheric particles. These particles can be trapped on the substrate surface by the condensing thin film, leaving "pinholes" or other surface distortions. Since sputtering generally takes places at pressures of about 10^{-3} Torr, it is desirable to have pumping systems capable of achieving base pressures which are several orders of magnitude below this range, usually 10^{-5} Torr or less before flushing the system with a gas for sputtering.

Permanent magnets are set up behind the cathode---which surrounds the loaded target---such that the magnetic field is normal to the flat surface of the cathode. This creates an electron trap, allowing electrons to enter the area and due to columbic force but keeping ions from escaping. The inter-electrode spacing in the sputtering gun needs to be smaller than the mean-free path of the collision between particles to prevent arcing between the cathode and anode. A gas, generally Argon (Ar), is introduced into the chamber and any positive ions are attracted to the cathode at pressure around 10^{-2} Torr has a mean free path of collision around 1mm loaded target. The ions strike the target, ejecting atoms from the target by means of momentum transfer AND emitting more electrons to join those in the electron trap. The created electron trap also increases the frequency of collisions between electrons and any neutral gas atoms, creating more positive ions that will strike the target. The atoms ejected from the target then form a vapor that is neutrally charged and can escape the electron trap, which condenses into a thin film on the substrate.

With planar magnetron sputtering, high deposition rates with lower voltages are available. This is due to the cyclical, almost self-perpetuating, nature of the process (each striking of the target creates more electrons which will create more positive ions which will strike the target and start all over again).

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GUN SHUTTER ASSEMBLY

The shutter assembly for the Magnetron gun is to be followed in the order shown below. There are chances of spacing errors which an operator has to avoid during assembly of the guns shutter. During the process run, if the operator has to adjust height of the guns, you will have to follow some steps while disassembling the shutters and assembling it back. The process chamber along with the sputtering guns and shutter assembly is shown below.

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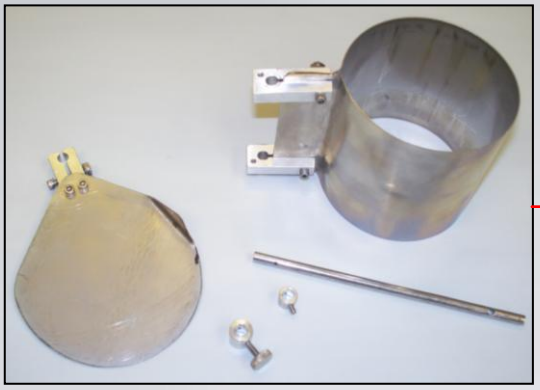

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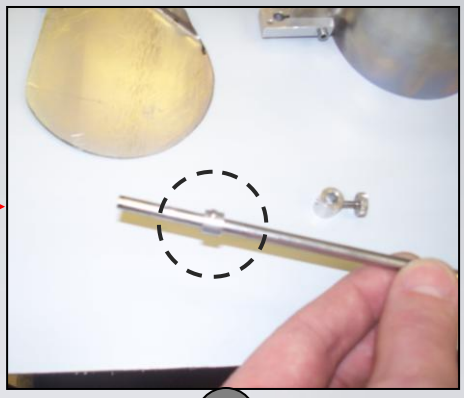

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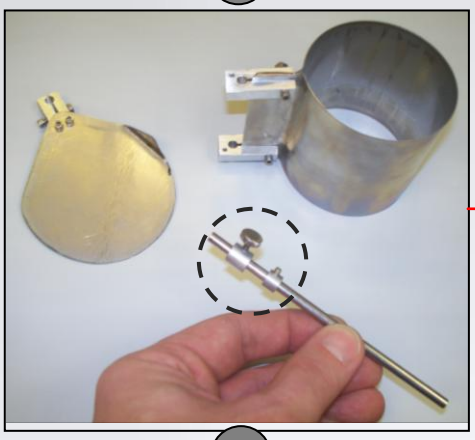

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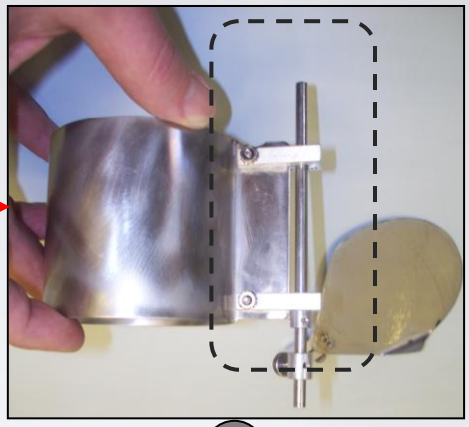

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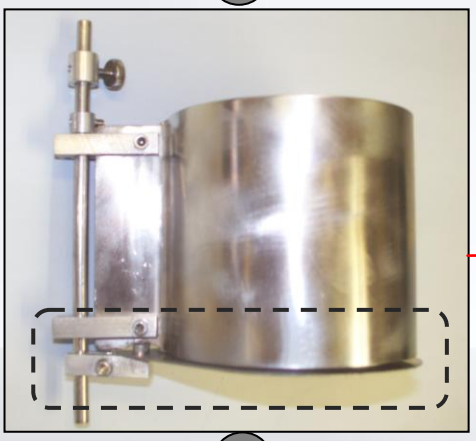

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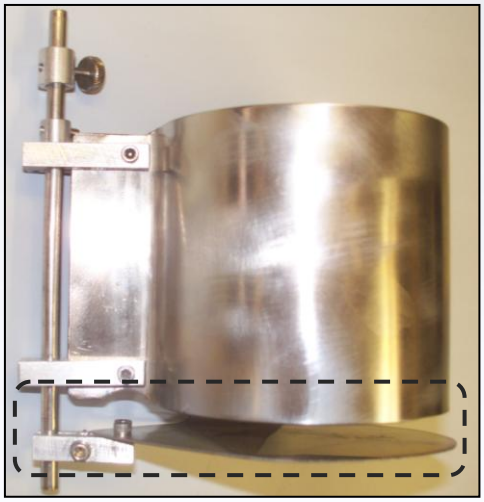
COMMON ERRORS DURING INSTALLATION OF SHUTTER

Shutter edge is inside the gun shield

The spacer/leveler is not at the right position, see result below



There is a gap between shutter and gun

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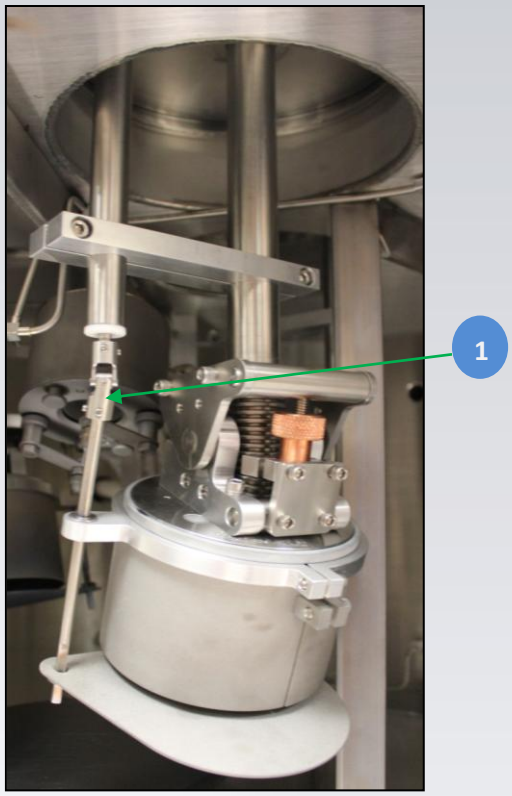
ADDITIONAL SYSTEM NOTES

MAGNETRON GUN HEIGHT ADJUSTMENT



To adjust the distance from the sputter guns to the sample stage:

1. Loosen the vacuum quick coupling connection on the outside of the chamber.
2. Loosen the socket head bolt on the Collar on the outside of the chamber with an appropriate Allen wrench. It is not necessary to totally remove the collar.
3. Inside the chamber, loosen the Shutter Height Adjustment Pin (marked as 1) so that the cable is free to move up and down depending on desired position.
4. Once final position of the gun is set, tighten the Collar on the outside of the chamber.
5. Now tighten the vacuum quick coupling connection on the outside of the chamber. This is necessary because as vacuum builds in the chamber, the vacuum will pull the gun down further into the chamber unless the collar is tightened.
6. Reattach the Shutter to the appropriate height, and tighten the Shutter Height Adjustment Pin to secure the shutter. Note: Please be sure to have the shutter assembly in the closed Position relative to its' position prior to adjusting the sputter gun.

To remove the shutter assembly from the sputter guns' anode cap:

1. Inside the chamber, remove the Shutter Height Adjustment Pin (marked as 1) and remove the shutter assembly slowly in a downward direction from the Magnetron Guns' Anode Cap.
2. You may have to apply some pressure to fight against static friction of the stainless steel chimney against ht stainless steel; anode cap

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TARGET MOUNTING

To ensure purity and to prevent contamination, it is important not to touch (wear powder free Latex or powder free Nitrile gloves) any internal components including shields, targets, substrates, samples, and guns with exposed skin.

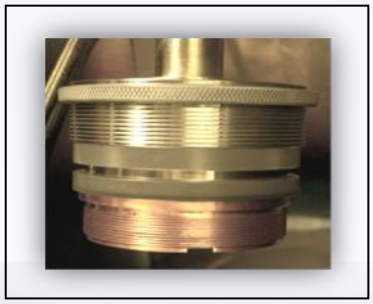
<u>To mount a target in the magnetron gun, do the following:</u>

1. First, unscrew the Anode Shield (1) to expose the Target Holder.
2. Then, unscrew the Target Holder & the Internal Plasma Shield (2&3). They will come off together.

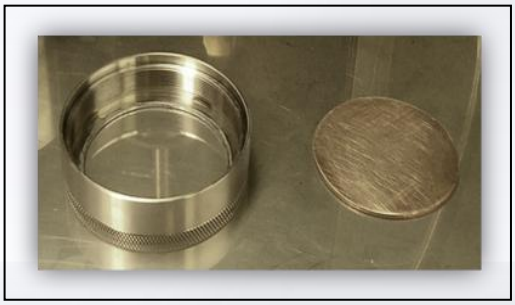
The gun is now disassembled. Refer to the pictures below as a guide:

Anode shield | Target holder | Internal Plasma Shield

Gun with anode shield removed



Gun with target holder & internal plasma shield removed



Target holder & internal plasma shield | Target

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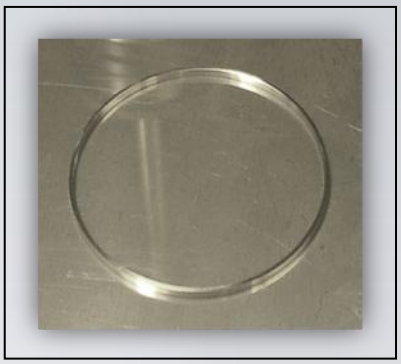
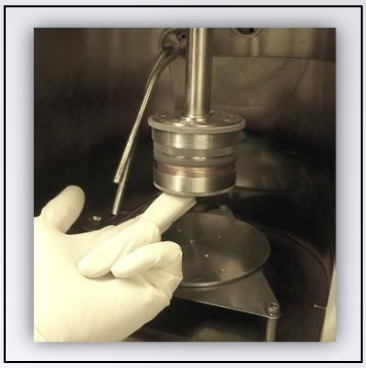
To load a target into the Target Holder:

1. Place the Internal Plasma Shield on the Target Holder.
2. Place the target in the Target Holder.



NOTE: When using a target that is thinner than 1.6 mm thick, place the Target Spacer Ring in the Target Holder BEFORE placing the target into the Target Holder. This will help ensure the thin target will make good contact with the cathode.

NOTE: Be sure the target is clean and that it does not come in contact with the skin to ensure purity. A short process run (about two minutes at 5mA DC) is recommended to clean the surface of a new target before any coatings are made. If the target is carbon, or has a high coefficient of thermal expansion, cut a target sized circle from a piece of aluminum foil and place the aluminum foil under the target. This is suggested to ensure good thermal contact.



To mount the target and Target Holder onto the gun:

1. Place the Target Holder Assembly [the Target Holder, the Internal Plasma Shield, the target and the Target Spacer Ring (if used)] onto the gun and screw it on a few twists. Do not tighten it yet.
2. With the Target Assembly not yet tightened, push UP on the target with your finger and make sure the target itself is centered in the cathode. The cathode is recessed to accommodate the target, and the target must be seated properly in the cathode for proper functionality.
3. While still holding the target in place, tighten the Target Holder Assembly on to the gun until it is snug.

NOTE: If the target is seated improperly due to poor mounting technique, erroneous results can occur because of bad electrical and thermal contact from the target to the gun. Be careful when tightening non-metals as over tightening can cause them to crack. \

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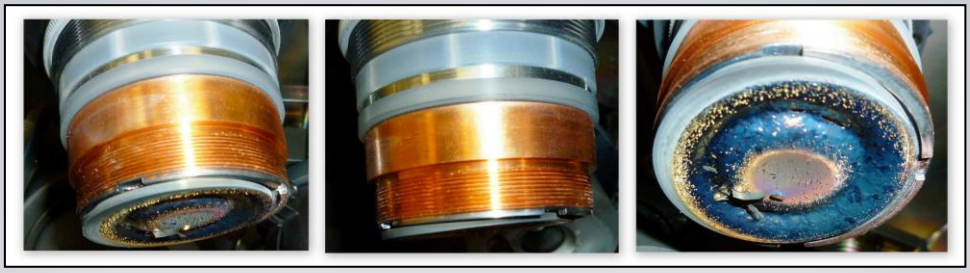

Possible Damage can occur due to improper mounting techniques of sputtering source

Mount the Anode Shield and set the correct spacing:

1. Raise the textured anode shield Locking Ring (4) a few twists higher on the gun.
2. Twist on the Anode Shield until it is almost touching the Target Holder.
3. Use the supplied gap tool (5) to ensure you have the correct gap between the Anode Shield and the Target Holder: place the gap tool between the Target Holder and the Anode Shield, and with the tool in place, twist the Anode Shield up until the correct gap is achieved 1.6 mm.
4. Then twist the anode shield Locking Ring (4) down until it meets the Anode Shield, and tighten the ring against the shield. This will prevent the shield from moving and retain the required gap for proper operation.
5. Finally, check the gap again with the gap tool to ensure all is correct.

TARGET MAINTENANCE

Ramp Rates:

Power should be ramped up SLOWLY to avoid arcing. Typical ramp rates for oxides are 10 Watts p/hour p/square inch of target surface area. A reasonable ramp rate for non-refractory metal targets is 50 Watts p/hour p/square inch of surface area.

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You may experience some build up of sputtered material on the centerand outside the racetrack of your target. It may be necessary to remove this material periodically in order to avoid arcing during operation. This will allow continued operation of your target at the maximum power.

TARGET HANDLING

When working with a vacuum chamber and specifically, a sputtering system, proper target handling is essential. Any residual build up of grease, dust, and old coating will trap water and other contaminants which will impede your ability to achieve a good vacuum. This will, in turn, produce films of poor quality. Target arcing, surface roughness in deposited films, and trace chemical impurities are often times linked to dirty sputter chamber, guns and targets.

- Metal Targets can be cleaned using an alcohol wipe with a lint free cloth. A short period of pre-sputtering is recommended.
- Oxide & Ceramic Targets can be cleaned using a non-impregnated "scotch bright" pad. After removing the contaminant, wipe the surface with alcohol using a lint free cloth. A short period of pre-sputtering is recommended.

TARGET STORAGE

- We recommend that you always keep your targets, metal or oxide, stored under vacuum. To assist you, we can ship targets in vacuum sealed poly bags.
- Gloves are required for the safe handling of the target. Do not touch the sputtering target with your bare hands.

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SYSTEM NOTES & OPERATION

SAFETY INTERLOCKS FOR POWER CUTOFF

The Thin Film PC Controlled Magnetron Sputtering system is designed with safety interlocks. Review the following before operation:

Neither the RF nor the DC power supplies will generate power unless the requirements of the safety interlocks are met. The following conditions must be met before the safety interlocks will be satisfied:

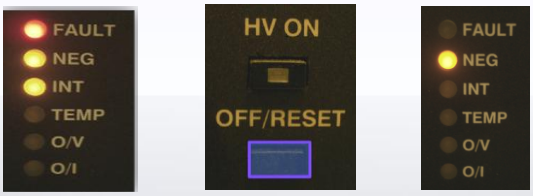
1. The coolant water must be circulating.
2. A sufficient chamber vacuum should be achieved as determined by the set points that are programmed in the Vacuum Gauge Controller of the system and can be viewed on software in computer.

NOTE: User must read power supply manual before the start of operation. All necessary safety interlocks are provided for this system.

FOR DC POWER SUPPLY:

On a DC power supply, if the FAULT and INT lights are illuminated (see picture to the right) then the DC power supply will not activate. If this is the case, to enable the power supply, first make sure the requirements listed above are being met. Then press the **OFF/RESET** button on the DC power supply. This will reset the safety interlocks and enable the power supply. (The OFF/RESET button is directly under the HV ON button)

If the safety interlocks are satisfied, the FAULT and INT lights will go out and just the NEG light on the DC power supply will illuminate. Once just the NEG light is illuminated, then you can proceed with sputtering with the DC power supply.



SAFETY INTERLOCK INDICATOR PANEL

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MATCHING NETWORK CONNECTIONS FOR RF POWER SUPPLY

These connections should be verified after shipping if your system includes an RF Power Supply:

- Matching Network Control- Ensure this is connected properly and tightly only by hand.
- RF Power Input - Ensure this is connected properly.
- RF Power Output– Connect power cable from Magnetron Sputtering source.

Note: Do not use any mechanical tool when connecting coaxial cable to either input or output of RF or DC power supply and Magnetron Sputtering source.

Note: Do not use any mechanical tool when connecting the type N connector coaxial cable to either input or output of RF or DC power supply and Magnetron Sputtering source. Please use only hands to tight connector and make sure the Nut on the connector is tight to as it can cause problems mostly during RF operations.

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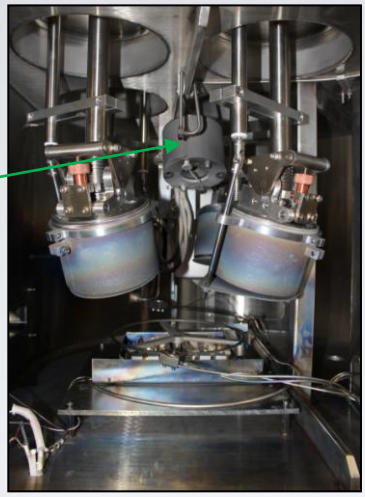
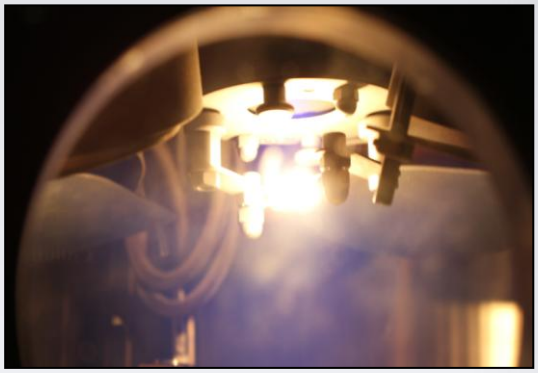
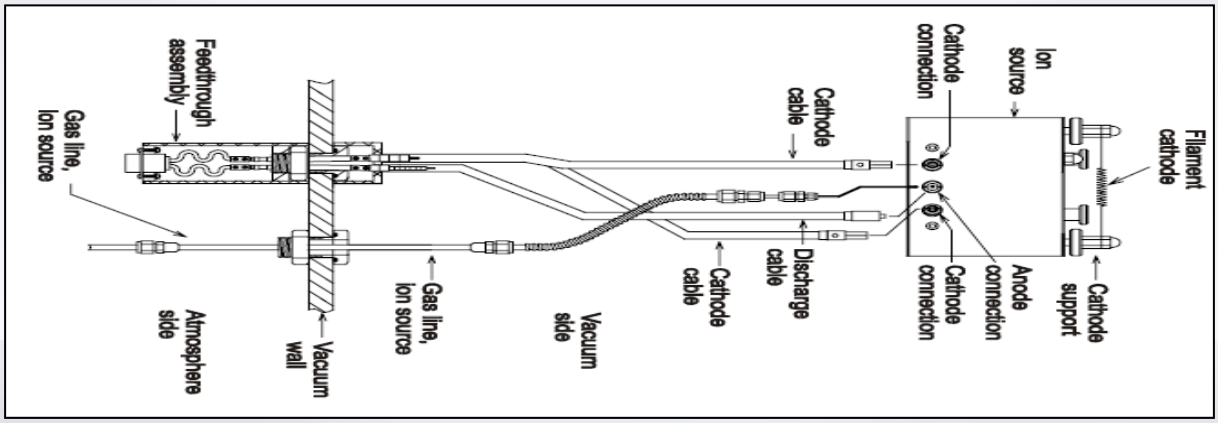
K&R GRIDLESS END HALL ION SOURCE: (EH-400)





ION SOURCE IN PROCESS CHAMBER AND AUTO CONTROLLER, FILAMENT CONTROLLER & DISCHARGE CONTROLLER



Courtesy: Kauffman & Robinson Product catalog

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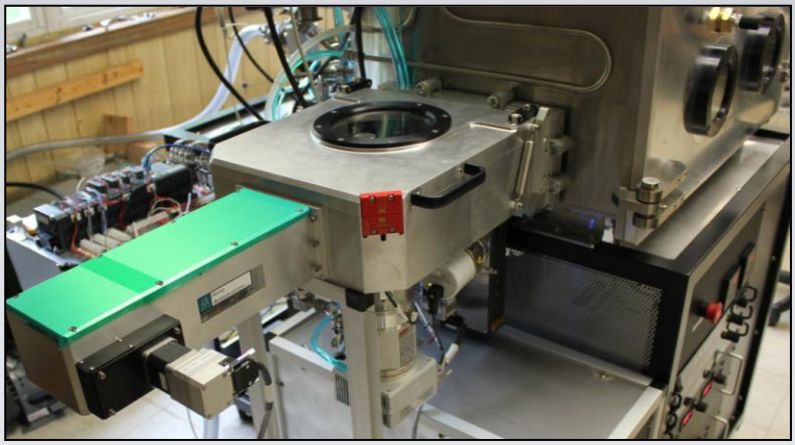
LOAD LOCK (SL-200) INTEGRATION:



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FAMILIARISING YOURSELF WITH THE PC CONTROL OPERATING SOFTWARE

Operation of the system is accomplished by using Thin Film software developed by Torr International and is installed in Windows operating system based computer. All prior communications to I/O hardware, vacuum pump and other controllers are controlled by Ethernet connection. Deposition is controlled using a Thin Film Deposition card installed in the computer, which interfaces to the crystal sensors and monitor all process related interlocks of the power supplies. The Thin Film Deposition Card is interfaced through program which allows for single or multi layer processes with each layer being set for either timed power or crystal sensor rate control. Crystal sensors are used to take feedback in order to control rate and final thickness. **Torr-Nanotech** -multi tool program interfaces with the SQS-242 Thin Film Deposition Control Software which allows automated and/or multi step recipes.

OPERATION OVERVIEW

- SYSTEM
  The Torr-Nanotech MagSput multi tool consists of a vacuum system, substrate stage mechanism, substrate rotation and four 4” and one 2” magnetron sputtering sources. The Flex type sputtering sources include Three Dedicated DC Magnetron sputtering guns and one Dedicated RF Magnetron sputtering Gun, capacitance gauge and full range gauge, three mass flow controllers. Pumping is done by 1000 l/sec capacity turbo pump with a water cooling water lines and a matching double stage rotary pump.

- CONTROL
  The system is coupled with thin film deposition controller and thin film deposition software. System control is accomplished by a Lab-View based Graphical User Interface PC controlled software developed by Torr International Inc. (**All Rights Reserved**). This Torr-Nanotech MAGSPUT-multi tool.exe has been developed in PC control software provided by Torr International Inc. and Programmable Logic Controllers. All communication to PLC is done via an Ethernet connection. Communication to Temperature controller and Turbo pump is accomplished via a serial interface.

- USER INTERFACE-MAIN PANEL
  The user interfaces with the control software from one main panel window and several auxiliary panel windows. Current values of the acquired data like pressure and temperature are displayed as well as the current state of the process control. The far left top of the panel

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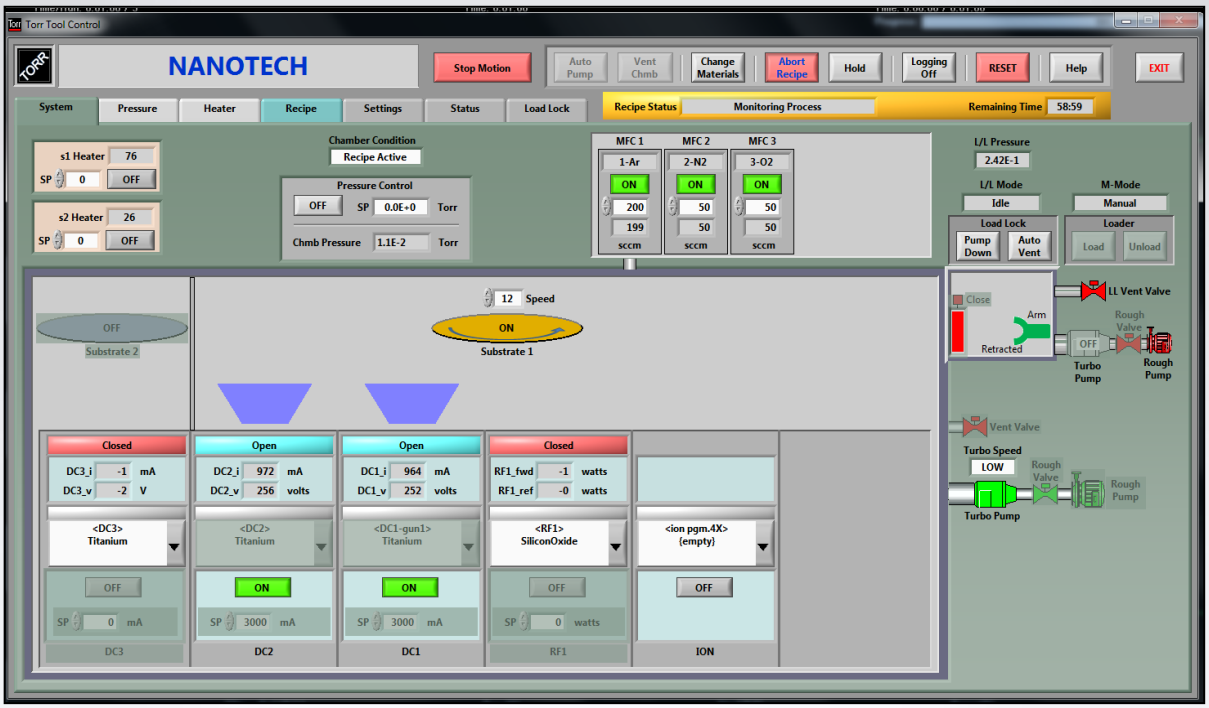
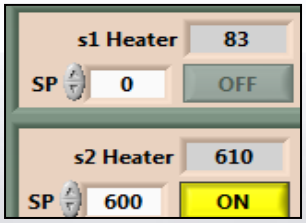
contains the function buttons like **(System, Pressure, Heater, Recipe, Settings, Status & load lock**) in a Gray shaded Area. Next to the function buttons, is the depiction of the chamber and associated valves, pumps and controls etc. Gas control panel is located on right top of the software panel with three mass flow controller where you can select the amount of flow in terms of SCCM. Pressure control and Heater control are displayed on left top side. The substrate stage rotation panel is in centre of the system panel. The sequence state is displayed on the top right portion of the screen with a multifunction display of recipe status and a time remaining is displayed when applicable. Access to the auxiliary panels is accomplished by using buttons on right top side on top of screen **(Auto Pump, Vent Chamber, Change Materials, Start Recipe, Hold, Logging OFF & RESET)** in grey shaded area. This buttons allow user to process Auto Pumping, Venting chamber, Change process Materials, Auto Start Recipe, Logging ON and OFF etc, RESET the software and system.



TORR MAIN COMPUTER CONTROL INTERFACE PANEL



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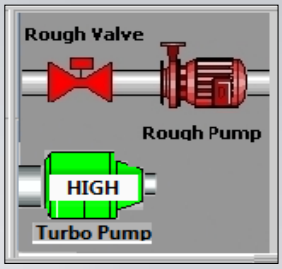

- Red Indicates an OFF state or an alarm active such as an Interlock Failure.
- Green Indicates an ON or OK state for most indicators.
- Yellow Indicates the "transit stage" for Heater and Sequence State process only.

USING ON/OFF CONTROLS

The user can left-click on any enabled control to turn it ON or OFF whether it be a control such as a valve or a button such as Auto Pump, Auto Vent and Start Recipe etc. Disabled controls appear grayed-out and cannot be activated. Some buttons are momentary and some act as switches which will change color and text to indicate that they are on.

VALUES

Numeric control values can be adjusted by either clicking in the field then entering a number or By clicking the increment/decrement arrows on the control's left side. If a number is directly entered the user must either press the ENTER KEY or click an area out of the control for the new value to be accepted.

USER SELECTION CONTROLS

Some of the available controls display multiple selection when the user "CLICKS" on them. For example the shutter selection is done by clicking on the RED shutter control just above the RF/DC sputter gun button. This will allow the user the flexibility to control all process by just one click. User can change the selection of the desired operating sputtering guns' simply by clicking on RF supply panel by selecting RF gun and DC Supply to select either DC gun1 or DC gun2 from the main control panel. Clicking in the middle of the turbo pump display will allow the user to select the requested speed: OFF, LOW and HIGH.

- Event Log: Event Logs can be viewed by pressing the Log button to bring up the Event Viewer panel. System events and alarms are indicated in this Event log with alarms noted with a bold, RED font.

- Errors: Errors will be displayed on a pop-up panel. Once the fault has been fixed, the error can be cleaned by pressing the CLEAR button on this panel.

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- Exiting the Program: The system must be in the STANDBY mode to exit the program. Pressing the EXIT button in the top right-hand section of the screen will display a dialog box asking if the user wishes to exit the program. The system can always be placed in the Standby State by pressing the RESET button. STAND BY engages the main controlling procedure for the system then you can click on EXIT button to exit from the software and shutting down the system.

BEGINNING SAMPLE OPERATION OVERVIEW

Before beginning make sure all of the following operating specifications are met;

- Cooling water at 2 gal/min (7.57 liter/min), 20-24ºC, with 3/8" Pisco fittings
- Compressed air at 5-7 bar (72.51-101.52 PSI) (4.93-6.90 Atm).
- Process gases like Ar at 1.10 bar (16 PSI) (1.08 Atm).
- Dry N_2 for venting at 1-1.2 bar (14.50-17.40 PSI) (0.98-1.18 Atm).

Note: All gas sources to the system MUST have an operating safety relief valve after the gas source pressure regulators for safety on system.

1. Make any other configuration changes to the system that your process requires such as gun positioning, load samples, etc. (Refer to the operation section for your desired sputtering process for any specific instructions).

2. Make sure the chamber door O-ring and the contact surface of the O-ring is clean. Then close the chamber door and latch it.

3. Turn On the system main power feed and then the system's main breaker on the rear side of the system.

4. Turn on the computer and after the operating system has completely booted click the TORR-NANOTECH MAGSPUT multi tool icon on desktop. The Thin Film Deposition control software will automatically start with the Torr program. If not then just double click on SQS-242 icon from the desktop.

5. The systems Main Power indicator will illuminate, However all other systems will present themselves powered down and non-operational until PC Control software is engaged.

6. The software will engage the system PLC and when the Watch Dog System Timer has been satisfied, this will engage the main system power control relay enabling system power. All switched on supplies will illuminate.

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7. After the system engagement vacuum pumping can be commenced. Simply click the Auto Pumping button and the rough pump will engage as long as all safety interlocks are satisfied. Any errors will be displayed on screen.

8. When the system base vacuum has been reached you can monitor in Torr-Multi tool program in software provided by Torr International Inc.

Note: The pumping operation can be engaged manually (in steps) by clicking the appropriate icons. Non engageable fields will be grayed out and not engage until requirements on system are met, such that the appropriate user settings have been reached. Use reference of HELP FILE for all settings in software provided with the manual.

SAMPLE OPERATION:

The steps involved in automated controlled recipe process is done by thin film deposition software environment, creating the process itself.

These steps are as followed:

1. Select a desired **MATERIAL** for creating recipe. There are number of materials pre-programmed for tool within the system, this most of the time will be a simple material selection within software menu.
2. Create a **FILM** using the selected Material.
3. Create a **PROCESS** using created a Film.

STEPS TO CREATE RECIPE: MATERIAL, FILM AND PROCESS

NOTE: THE PROCESS MENTIONED BELOW IS JUST FOR FUTURE REFERANCE. TORR INTERNATIONAL INC HAS ALREADY CREATED PROCESS IN THIN FILM DEPOSITION SOFTWARE. SO DO NOT CHANGE ANY OF THE SETTINGS, DONE IN COMPUTER IN ORDER TO GET FINE OPERATION.

Open the Thin Film Deposition software program (SQM-242),installed in computer and from within program.

1. Click on EDIT + MATERIALS menu. To add a new material you should select the proper material for the sputtering process provided in SQM-242 software. Check for the **DENSITY** & **Z-FACTOR** of the material as per desired recipe. Refer to the R.D.Mathis reference guide which has been provided for sputtering materials and their respective parameters.
2. For example select TITANIUM and examine its associated Density and Z-factor for crystal measurement and control. On selection of the many, pre-existing configured sputtering materials for use in creating FILMS, this step can simply be passed over.

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3. Close this MENU selection. Select EDIT + FILMS menu. Select NEW FILM NAME and type "DC1-Ti" for Titanium using DC1 supply and magnetron gun. Looking at the associated films menu box you will see "DEPOSIT" Tab which is for the PID values when using PID rate control. Usually, the standard values are P:25, I:0 sec, D:0 sec. You can then select the condition for ramping and soaking settings if desired. Please make sure that Rate Sampling is Continuous in order to monitor process in better manner.
4. To Enter "PRE CONDITION" click on CONDITION Tab. Now enter "ramp 1" time of 0.5 minutes, a "ramp 1" power value of 8% and a "soak 1" time on 1 minute. The second column is for a "ramp power" and "soak period" which can also be entered if desired. This is a good place for preconditioning the rate emission and surface temperature of a target. Especially with dielectric materials whose thermal surface temperatures are generally not so conductive as metal and can vary greatly dependant on material target thickness and power level.
5. Select SOURCE/SENSOR Tab, select the material "Titanium" and enter 50% Maximum power (leave the Slew rate at 100%) and set the Tooling factor (The rate of True Deposit vs. Deposit measured for correction) to 500. It is a good habit to always limit the maximum power per material.
6. Close the Film section and click on Edit to open Process. You can see your list of created Films for desired process. The user can select desired process for their recipe by clicking on the list. Then you can see Layer which consists of Film, Output (RF/DC), Input Method (Timed Power), Set Point, Final Thickness, Time end point, Start Mode (Manual, Auto, Skip Pre/post, Continuous). The user can change the parameters as per desired requirement.
7. The user can create multi layer recipe depending upon research by adding another prepared films in same process.
   NOTE: Torr has already created sample processes for the four sputtering sources as well as the RF cleaning electrode. ***Note: The above steps are provided only for test references and should not modified or deleted.***

NEXT STEP IS TO CREATE SECOND FILM FOR RF POWER SUPPLY & MAGNETRON GUN FOR THE INTENDED MATERIAL OF SiO_2

8. Close this MENU selection. Select "EDIT + FILMS". Select NEW FILM NAME and type "RF-SiO" for RF sputtering system. Using this step, enter the pre-existing material of SiO with a power limit of 50%. It is advisable to make a New FILM for each process gun with its applicable material you use in processes. Even though using the same materials since the characteristics of each gun vary. CLOSE THE FILMS MENU.

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9. Now select "EDIT + PROCESS" and click on NEW PROCESS NAME, then enter name for the process called PROCESS 1.
10. The next step is to select power supply and gun to be used for deposition.
11. Under system set up section, select an appropriate sputtering guns (DC1-gun1 or DC1-gun2). **NOTE:** For performing the RF sputtering process select the proper magnetron gun and material you have already placed in the sputtering gun. PC control software also controls the motorized shutter assembly for five Magnetron Sputtering Guns.
12. Next selection is for INPUT selection, either SENSOR or POWER. Now whichever mode of operation selected the preconditioning ramp and soaks are applied the source selection mode of operation is for the deposit phase of operation and per the settings of the SQS software settings pre rate of deposit levels are matched before opening the substrate shutter on pre conditioning.

    CREATE A LAYER FOR SAMPLE PROCESS 1:

    - Select INPUT + TIMED POWER for fixed power operation.
    - Set the POWER level and PERIOD of time for the process.
    - Now create a second layer for process 2 for SiO
    - Select the applicable sputtering gun (RF sputter) and supply for SiO target.
    - Keep the power and time settings as it is for second process.
    - Close the MENU box. And close SQS-242 software to update all recommended settings.

    NOW YOU CAN CALL THIS PROCESS FROM TORR—NANOTECH MagSput MULTI TOOL PROGRAM WITH APPROPRIATE GAS FLOW SETTINGS for THREE MFC.

13. Open Torr—Nanotech MagSput Multi tool file and choose selection CHANGE MATERIALS. Under the menu change the RF gun material to silicon oxide and the DC1 gun to Titanium. This helps user to know what current targets have been entered on system.
14. Select RECIPE panel and then you can import a recipe (or all recipe for multi process) at a time. You can also Edit Step by changing Time cutoff, Temperature Set point, Temperature Stabilization time, Flow rate for three mass flow controllers. Make sure to click on Modify Recipe Step to save the changes. Now you can close the RECIPE panel. Click on "Start Recipe" and recipe will automatically RUN for the sputtering process. All deposition process controlled parameters monitored right from PC Control Software developed by Torr International Inc.

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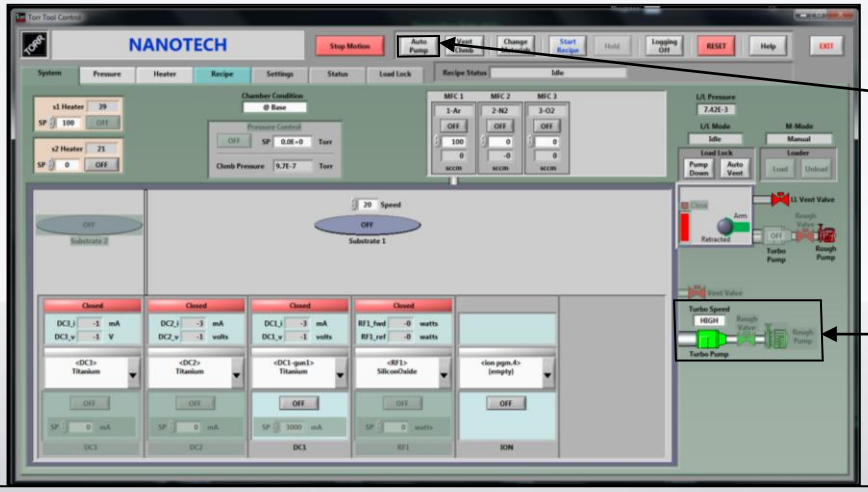
VACUUM OPERATION

Before starting, ensure the Main power Breaker is set to OFF.

1) Check all electrical connections prior to start the vacuum process.
2) Check for the cooling water line connecting and make sure water is on, feeding the system with the appropriate pressure requirements. Also check for remaining required system utilities like compressed air, process gases and water chiller connections.
3) Make sure the chamber door O-rings and the seat of the O-rings is clean. If not then clean this surface with laboratory graded alcohol (99%). Please allow some time to evaporate alcohol prior to closing the chamber door and latching it. Then close the chamber door and latch it.
4) Make sure all the deposition controlled settings, process recipes in SQS-242 program, sputtering materials and position of magnetron sputtering guns are an appropriate before the start of the process.
5) Now, power ON the system by switching the Main Power Switch to ON. The components of the system should power up. If a component does not have power, be sure the individual component's power switch is ON.
6) Click on the Torr Multi tool software icon, located on desktop. Please allow couple of minutes for software to check all interlocks and wait till it performs the system check digitally. If the software finds any kind of system error, it will indicate immediately by continuous flashing in STATUS panel of the software. If you do not find any error then you are good to start vacuum process.
7) Now you can click on the AUTOPUMP icon to automatically engage the turbo pump. The operation of a roughing pump will engage and vacuum will start to build.



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Fax: (845)561-7731
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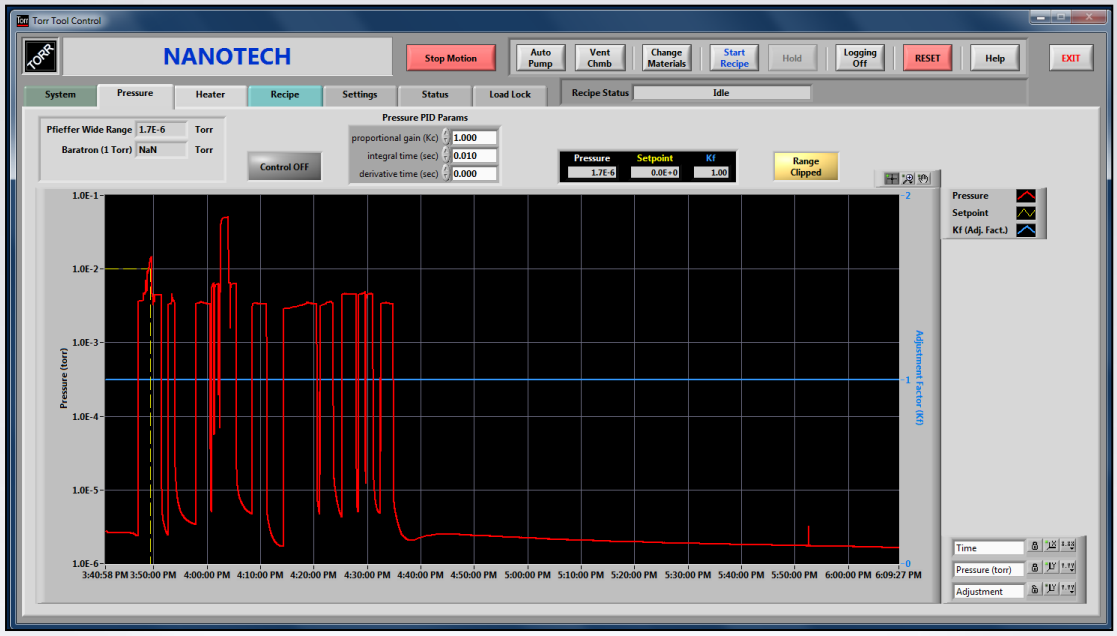
8) While the initial vacuum is building, UNLATCH the chamber door. As long as there is a vacuum in the chamber, the door will not open. NOTE: Unlatching the chamber door is a safety measure to prevent accidental over pressurization of the chamber during venting process.
9) The turbo pump controller will activate the turbo pump when a sufficient vacuum has been achieved as determined by set points that are programmed under system settings in the PC control software.
10) The factory default settings are as follows: Refer to HELP FILE provided with the system for all process settings. DO NOT TRY TO CHANGE THEM.
11) Monitor the pressure of the process chamber from PRESSURE panel within PC control system software provided.



1.7E-6 TORR
CHAMBER PRESSURE FOR SPUTTERING SYSTEM

ACHIEVING BETTER VACCUM (PUMP-PURGE)

In order to improve vacuum it may be advantageous to perform one or more partial pump-purge cycles with dry N_2 as described below. This involves manually performing partial pump-downs of the chamber to a desired rough-vacuum level and then partially filling the chamber with dry N_2 before re-pumping.

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The introduction of dry N_2 helps to facilitate the removal of other gases, especially water vapor, during the subsequent re-pump cycle. This may allow for higher vacuum pressure benchmarks to be reached more quickly.

Note: If the Turbo Pump is operating anywhere near full speed around 38000 rpm, DO NOT perform pump purge cycles. Ideally these cycles should be used before the Turbo Pump even engages.

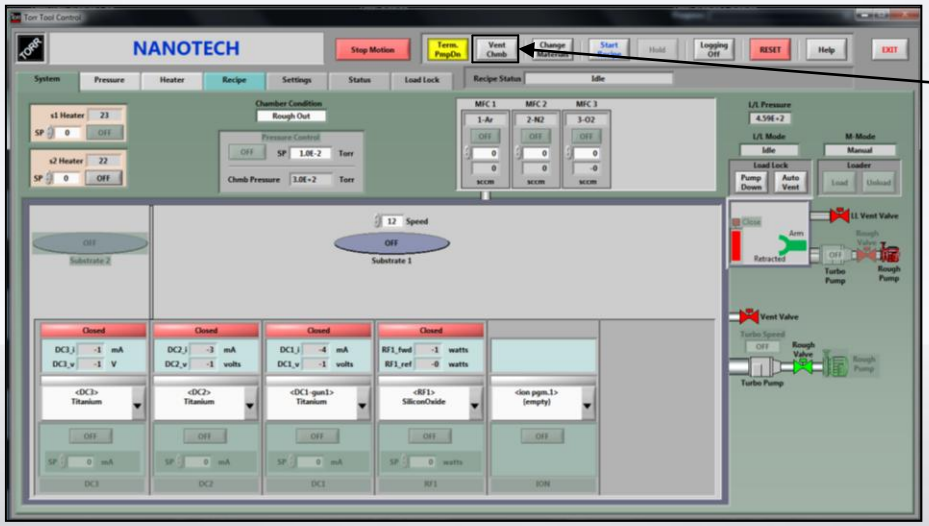
To pump-purge the system:

- Let a vacuum build in the chamber as prescribed in the above Basic Vacuum Operation section. Once the vacuum has reached about 0.1 to 1.0 Torr, Turn OFF the Auto Pump icon.
- Vent the chamber by turning ON the Auto Vent icon. The pressure of the dry N2 that is fed into the system will dictate how long venting takes. You can monitor the pressure from the PRESSURE panel in software.
- Once venting has completed (approx 200-300 Torr has been reached without opening the door), turn OFF the Auto Vent icon.
- Repeat steps above as many times as desired and then pump the system down, following the steps outlined in the basic vacuum operation section.

DEACTIVATION

Venting the chamber is relatively more easy. Please follow following steps in sequence to Stop the vacuum system and properly vent the chamber.

<u>NOTE:</u> It is recommended to wait until the pressure is about 10^{-1} Torr before venting. You can insert Gas for small amount of time to drop the vacuum in the process chamber.



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- Confirm that the chamber door latches are “disengaged”. This will ensure that the chamber does not become over pressurized when venting.
- You can vent the process chamber by clicking on VENT CHAMBER ICON from software. This will slow down turbo pump and roughing pump. Now, wait for the pressure to reach up to atmospheric pressure. You can monitor the pressure with the PRESSURE Panel.
- WAIT for the procedure to complete. You will not be able to open the chamber door until the internal pressure approaches atmospheric pressure. Once venting has completed, you can open the chamber door.
- Switch OFF the Magnetron Sputtering System Main Power switch.

NOTE: All the settings and system operation through Torr Multi toll software is mentioned in detail in separate HELP FILE.

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MAINTENANCE

IMPORTANT: MOST USER EXPERIENCE PROBLEM WITH COATING SYSTEMS ARE THE RESULT OF IMPROPER MAINTAINANCE AT THE USER FACILITY: Standard maintenance for this combination is very simple but it is also important. The electrical and control systems require no regular maintenance if properly used. The vacuum system does require attention for optimum system performance and film quality.

PROCESS CHAMBER

The chamber should be cleaned whenever the view port sight glass becomes covered with deposition materials. Remove the O-rings from the groves in the chamber periodically. Do not use a sharp instrument to remove O-ring, as they may be cut and then will could cause vacuum chamber to leak. Clean the O-ring with ISOPROPYL alcohol or ethanol. You may choose to reapply high vacuum O-ring grease to a cleaned or new o-ring, only using a very small amount just lightly coat the surface of the entire o-ring. Clean the chamber with laboratory graded 99.99% alcohol and light duty scouring pads. Let the chamber and O-ring groove dry thoroughly and then replace the O-ring.

TWO STAGE ROTARY MECHANICAL PUMP

See the manufacturer's OEM Manual for detailed instructions of Maintenance. The frequency with which repairs are performed depends on the process and presence of substances that shortens pump life (dust, abrasives, solvents, water, and chemically aggressive substances). The pump must be cleaned at regular intervals of time.

CAUTION:-

Do not clean the plastic or rubber components of the pump with Alcohol. Use only the necessary amount of direct drive fluid. An excess of direct drive fluid may sometimes compromise proper operation of the pump. We do not recommend to change the oil until the temperature of the pump reaches to ambient room temperature. The drain and filler plugs must not be left open any longer than is necessary to change or to add direct drive fluid.

Maintenance technicians must:

- be aware of all applicable national directives concerning accident prevention during work on motor-driven pumps and should know how to apply them
- have read and understood all the sections on "Safety Rules"
- be familiar with the essential design features and operation of the pump
- know how to use and consult the pump documentation
- be concerned about proper operation of the pump

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THE MAGNETRON SPUTTERING GUNS

The anode and the target holder may require periodic cleaning. The gun parts may be cleaned with Scotch-Brite pads with water or alcohol. If water is used, be sure to rinse the parts thoroughly with 99.99% Isopropyl alcohol or ethanol and allow to dry before reinstalling. The Magnetron Source Anode assembly should be cleaned any time a target is changed. When running carbon or any dielectric material, the gun will typically require more cleaning, as a non-conductive build up on

the anode will cause the anode to no longer be grounded, and the gun will no longer ignite plasma. When there are noticeable flakes on either the target-clamping ring, or the anode assembly or source shutter assembly that should be cleaned. Be sure to inspect these two parts right at the anode gap where they are very close to each other. Any flakes can short the gun, rendering it useless until it is cleaned.

<u>ALWAYS USE LABORATARY STANDARD HAND GLOVES</u>:

To test the connectivity of cathode and anode of the gun for a short, put an ohmmeter between the target clamping ring and the anode. The resistance should be on the order of Mega ohms. Note that the gun input power cable must be unplugged from the gun in order to check an accurate reading. In order to test the gun under vacuum, make sure that the power supplies are off, and then unscrew the type N connector and test to the shell of the connector.

VACUUM GAUGE (PKR251)

Gauge failures due to contamination or wear and tear, as well as expendable parts (e.g. filament), are not covered by the warranty. Gauge contamination is influenced by the process media used as well as any present or new contaminants and their respective partial pressures. Continuous operation in the range of 10^{-4} mbar ... 10^{-2} mbar can cause severe contamination as well as reduced up-time and maintenance cycles. With constantly low pressures ($p < 1\times10^{-6}$ mbar), the gauge can be operated for more than one year without Cleaning.

<u>Contamination of the gauge generally causes a deviation of the measured values:</u>

• In the high pressure range (1×10^{-3} mbar ... 0.1 mbar), the pressure indication is too high (contamination of the Pirani element). Readjustment of the Pirani measurement system.

• In the low pressure range ($p < 1\times10^{-3}$ mbar), the pressure indication is usually too low (contamination of the cold cathode system). In case of severe contamination, instabilities can occur (layers of the measuring chamber peel off). Contamination due to insulation layers can

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even lead to a complete failure of the discharge ("Underrange" is displayed).

Contamination can to a certain extent be reduced by:

• Geometric protection measures (e.g. screenings, elbows) for particles that spread rectilinearly.

• Mounting the flange of the gauge at a place where the partial pressure of the pollutants is particularly low. Special precautions are required for vapors deposited under plasma (of the cold cathode measurement system). **NOTE: It may even be necessary to temporarily switch of the gauge while vapors occur.**

Adjusting the gauge

The gauge is factory-calibrated. Readjustment or cleaning may become necessary because of use in different climatic conditions, aging, or contamination. The cold cathode measurement circuit, which is dominant for low pressures ($<1\times10^{-3}$ mbar), is factory-calibrated. By way of contrast, the Pirani measurement circuit can be adjusted. Any adjustment has a negligible effect on the pressure range between approx. 10^{-2} mbar and 10^{2} mbar.

- Put the gauge into operation (if possible, in the position, in which it will be used later on).
- Evacuate the vacuum system to $p << 10^{-4}$ mbar, and then wait 10 minutes.
- Turn the nameplate counter-clockwise until the mechanical stop is reached.
- While depressing the tactile switch with a cylindrical pin (≈ø3 mm), adjust the <HV> potentiometer by means of a 1.5 mm screwdriver … … to 5×10^{-4} mbar **or** … to 4.2 V.
  After that, turn the potentiometer counter-clockwise by ≈120°.
- Vent with air or nitrogen to atmospheric pressure and then wait 10 minutes.
- Turn the nameplate clockwise until the mechanical stop is reached.
- Using the screwdriver, adjust the <ATM> potentiometer … to 1×10^{3} mbar **or** … to 8.6 V.
- Turn the nameplate back to its original position (it will catch).

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SUBSTRATE STAGE ASSEMBLY

Be sure that Main power to system is OFF while cleaning the substrate stage and make sure the POWER Breaker Switch is in the OFF position when the chamber door is open.

Make sure to clean the substrate stage using laboratory graded alcohol before the start of any thermal operation. Look for signs of flaking material or heavy build up within on the surface of the chamber and substrate assembly.

Note: Please read OEM's manual for detailed maintenance for each individual components. And follow the laboratory safety standards when operating the Magnetron Sputtering System.

TURBO PUMP AND THICKNESS SENSOR

Follow the manufacturer's instruction manual provided with the system for particular component for cleaning and maintenance.

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TROUBLESHOOTING

VACUUM

SYMPTOMS	ACTIONS TO SEEK
Cannot achieve a good vacuum	Check chamber "O-Ring". They should be lightly greased and particle free.
	Change dry scroll pump.
	Perform routine cleaning of chamber, pedestal, gun assembly, shutters and S.S. liners.
	Check vacuum gauge for contamination.

MAGNETRON SPUTTERING

SYMPTOMS	ACTIONS TO SEEK
Source fails to start	Check that the safety interlocks are satisfied. See the section on the safety interlock for power cutoff.
	Check for correct Gas pressure.
	Check for contamination which can induce arcing. Clean if necessary.
	Turn off the supply and call TORR International Inc.
System does not function or problem does not fit any previous description.	Contact Torr International Inc.

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RF MATCHING NETWORK

SYMPTOMS	ACTIONS TO SEEK
Source fails to start	Check that the safety interlocks are satisfied. See the section on the safety interlock for power cutoff.
	Check for correct Gas pressure.
	Turn off the supply and call TORR International Inc.
	Refer to SEREN manual for more specific matching network configuration problems.
System does not function or problem does not fit any previous description.	Contact Torr International Inc.

DRY SCROLL PUMP

SYMPTOMS	POSSIBLE CAUSES	ACTIONS TO SEEK
Fails to start	One or both fuses blown	Replace fuses Identify cause of overload. Check the line voltage and voltage configuration of the pump.
	Excessive voltage drop	Check size and length of cable.
Poor Ultimate pressure	System leak	Locate and repair leak.
	Poor conductance to pump	Replumb with shorter and/or larger diameter tubing
Hammering noise	Pump overheated	Check ventilation to pump Check ambient temperature.
Does not function or problem does not fit any previous description.		Contact Torr International Inc.

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Fax: (845)561-7731
E-mail: torr@torr.com

WARRANTY AND DISCLAIMER

The RF and DC Magnetron sputtering deposition system is warranted to be free from defects in material or workmanship under normal use and service for one year. Malfunctions of an instrument or other articles of equipment caused by abuse, incorrect installation or use, or neglect of the instrument or equipment by the purchaser are not covered by this warranty. No other express warranty is given, and no affirmation by Torr International, Inc., or its agents, by words or actions, shall constitute a warranty.

Torr International, Inc. fully tests and burns-in each system prior to shipment. Every effort has been made to ensure equipment arrives and remains safe and reliable. Safety interlocks are provided to prevent injury and must not be defeated or altered in any matter. If problems are encountered during initial set up, please contact Torr International, Inc. immediately.

Torr International, Inc. sole and exclusive obligation to an original purchaser under this warranty shall be to repair at its factory any instrument which is returned intact to Torr International, Inc. by the original purchaser, transportation and freight charges prepaid within 360 days after delivery of such instruments to the original purchaser, and which in the sole opinion of Torr International, Inc. has malfunctioned due to defects in original materials and workmanship. This remedy shall be the original purchaser's sole and exclusive remedy under this warranty. Torr International, Inc. shall not be liable under this warranty for any consequential damages including loss of profits, delays, expense, damage to goods or property used in connection with, or process by or in, the instrument or other articles of equipment covered by this warranty, or damage to such instrument, or for damages suffered as a result of personal injury.

Although schematic diagrams and troubleshooting guide are provided within this manual, Torr International, Inc. cannot be held responsible for damage to equipment or personal injury that may occur while attempting to troubleshoot or repair this equipment.

CONTACT INFORMATION

TORR International, Inc.
12 Columbus Street
New Windsor, NY 12553
Tel: (888) 622-TORR / (845) 565-4027
Fax: (845) 561-7731
Website: www.torr.com
Email: torr@torr.com
Manual Prepared By: Monark Suthar
Manual Certified By: Mike Droney (Project manager)

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LIST OF MANUALS

COMPONENT	VENDOR
PLC	AUTOMATION DIRECT: DL205
TV551 Turbo Pump	VARIAN
DS102 Vacuum Pump	VARIAN
Magnetron Gun	ANGSTROM SCIENCE
Temperature Controller	AUTONICS
DC power Supply	HV CONCEPT INC.
Baratron Gauge	MKS 626B
Mass Flow Controller	ALICAT
Vacuum Gauge	PFEIFFER: PK251
Auto Matching Network	SEREN: AT-3
RF Power Supply	SEREN:R301
Auto Matching Controller	SEREN: MC2
Deposition Controller	INFICON: SQM-242
Deposition Controller Software	INFICON: SQS-242
Computer	HP

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