OPERATION MANUAL

CHA MARK 40 EVAPORATOR

FOR

DIELECTRIC FILMS

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Contents

Introduction

The CHA Mark 40 Evaporator is designated for thin film deposition of dielectric materials. Due to the highly automated features of this equipment, the operator must be familiar with electron beam evaporation operating principles. Lack of e-beam experience while operating the Mark 40 can result in severe damage to the system and/or personal injury.

The Mark 40 provides versatile options to fit many deposition requirements. Single and multi-layer films can be deposited with up to four different materials. Thickness monitoring can be performed with a quartz crystal monitor or an optical monitor. The chamber can be baked out, and elevated deposition temperatures can be maintained. A liquid nitrogen cold trap is available for increased pumping speeds especially at elevated chamber temperatures. Background gas species can be detected and quantified using the residual gas analyzer. Planetary sample rotation provides better film thickness uniformity than single axis rotation systems. Samples up to four inches in diameter can be coated, a maximum of six four inches holders can be mounted, and twice that number for small sample holders. System base pressure is ~2 x 10^{-7} torr utilizing a ten-inch cryogenic pump. The pump is thermally protected from chamber heat by a louvered water baffle.

Equipment Rack Description

Description of the equipment will begin from the top of the rack.

1. Residual Gas Analyzer (RGA) – the RGA is used to determine background gas species in the chamber. The system is only operated at pressures less than 5×10^{-5} torr. This instrument is useful for determining if a small gas leak is suspected. Water content can be determined also. This information can be important if it's desired to characterize a baseline water partial pressure after a chamber bake out.
2. Granville Phillips 307 Vacuum Controller – the controller has four displays: Ionization Gauge 1 (IG1), IG2, Convectron Gauge A, and Convectron Gauge B. IG1 measures the pressure on the cryopump side of the gate valve when the valve is closed, IG2 measures the chamber pressure when the gate valve is open, Gauge A is not used, and Gauge B measures the chamber pressure in the range of 1×10^{-4} torr to atmospheric. Gauge B setpoint (relay 5) is 200 mtorr to close the chamber roughing valve and open the high vacuum gate valve. One IG2 setpoint (relay 1) is 1×10^{-5} torr to enable the heater control. The second IG2 setpoint (relay 2) is 2×10^{-6} torr to enable deposition. When the gate valve is opened, automatic filament control starts IG2 and shuts off IG1. When the gate valve is closed, the same control starts IG1 and shuts off IG2.
3. Omega Thermocouple Gauge – measures the temperature of the chamber in the sample region.
4. E-beam Power Supply On/Off Key –controls line voltage to the SR-10 power supply located in the service chase.
5. Mass Flow Controller (MFC) – controls the flow of O_2 gas into the chamber. Read out is in units of sccm. The adjustment knob is incremented in tenths of a sccm.
6. XINIX QCM – the quartz crystal monitor (QCM) controls the e-gun pocket selection, crystal head selection, ramp and soak conditions, evaporation rate, next program start

(NPS) criteria, physical film thickness endpoint detection, shutter actuation, and fault condition actions. Up to eight different processes can be programmed. 180 film layers can be stored with up to nine different deposition conditions.

7. SR-10 High Voltage Control, Gun Control, and Beam Sweep Control – the beam voltage is set with the High Voltage Control knob, Gun Control is normally controlled by the XINIX when the REM/LOC switch is in REM. In LOC position, the knob controls the filament current. The Beam Sweep Control is used to adjust the longitudinal and latitudinal sweep positions and amplitudes. The frequency has been set and should not need adjustment under normal conditions.
8. Eddy LMC-10 Optical Monitor – determines the optical thickness of a film for end of deposition (EOD) control.
9. Final Thickness/Shutter/Gas Control Panel – Gas 1 and Gas 2 can be controlled manually or automatically for each deposition layer. Gas 1 is oxygen, Gas 2 is not used. The crystal monitor or the optical monitor for each deposition layer can control final thickness. The Opt Mon Setpoint Hi and Low selection switches are not used with the Eddy optical monitor. These switches were used with a previous version. The position of these switches does not matter. The Setpoint Counter Hi and Setpoint Counter Low displays have been bypassed and are not required with the Eddy optical monitor. The Shutter control switch allows automatic, manual, and off conditions to be enabled. The Open indicator light displays the state of the shutter position.
10. Auto-Tech II – controls the vacuum chamber functions either automatically or manually.
11. Deposition Controller – the Ready, On, and Complete lights give the status of the deposition. Ready indicates all interlocks have been satisfied and deposition can proceed. On indicates that deposition is taking place. Complete indicates deposition is completed for each layer. The Auto-Man-Start rocker switch is used to determine auto or manual deposition cycling. The Cycle Complete switch is set to the final layer to be deposited. Sample heating is selected for each layer and can be either a PRE heat or CONT(inuous) heat condition. The Heater Soak Time is selected to

allow a heat soak period before deposition for the selected layers. E-B Aux switch is used to by-pass an interlock to run the e-beam in manual mode.

12. E.B. Gun rotation Control – crucible selection can be automatic or manual. The Process Selector chooses the XINIX Film Start number.
13. Fixture Control – rotation can be either auto, off, or manual. Fwd, Brake, Rev options provide rotation direction and stopping. The speed control knob ranges from Slow to Fast. The Off/On switch provides power for rotation in auto or manual mode.
14. LN2 Control – fills the cold trap with liquid nitrogen. The Auto position controls the level of liquid nitrogen. Manual overrides the Auto mode.
15. Heater Power Supply – controls the quartz heating lamps for heating the chamber. The Auto-Off-Manual switch allows automatic on/off control or manual on control. The thermocouple is located at the bottom of the chamber.
16. Austin Scientific Automatic Cyropump Control – provides temperature and pressure conditions of the cryopump. Used to regenerate the cryopump.
17. Cryopump Roughing Pressure Gauge – measures the pressure at the cryopump. If the pressure rises above the setpoint of 5 mtorr, the Granville-Phillips 307 Vacuum Controller power is shut off and no evaporation can be performed.
18. Mechanical Pump Breaker – turn on to activate the mechanical roughing pump. Power will be removed from the breaker when chamber automatically crosses over to high vacuum. Power is applied to breaker when gate valve is closed. This breaker should be off when the pump is not in use.
19. Sieve Trap Heater – not used in this system.
20. LN2 Flange Heater – heats inlet flange to cold trap to prevent icing. Must be on when using the LN2 Control unit.
21. Heater Breaker, System Power Fuses, RGA Valve Control – heater breaker provides power to the Heater Power Supply unit, System Power Fuses provide power to control circuitry, and RGA Valve Control provides manual or automatic valve control to the detector. Control should always be in AUTO mode to prevent damage to the detector.

Cooling Water

Cooling water for the e-gun and chamber is turned on with a set of valves in the chase behind the equipment. Open the Return valve then the Supply valve always in this order to prevent excess pressure loads on the evaporator cooling system. Close the Supply valve then the Return valve always in this order when turning off the cooling water for the same reason. If cooling water is not on or a low flow condition exists, the H_2O interlock light on the Gun Control Module will not illuminate.

High Voltage Power Supply

The high voltage power supply is an air-cooled unit and is located in the chase behind the evaporator. One main power switch is located on the side of the supply.

Oxygen Gas Bottle and Valves

The oxygen bottle is located in the chase behind the ICP. There is a valve between the wall mounted regulator and the bottle, and an in-line valve between the evaporator and the chase wall near the floor.

Liquid Nitrogen Dewer

The LN2 dewer is located in the chase behind the evaporator. The supply line valve should initially be barely opened to prevent liquid from streaming out of the top of the phase separator mounted over the cold trap. Adjust the valve for maximum flow without streaming.

Film Deposition

Programming the XINIX QCM

Depress the power switch to turn on the XINIX. A screen will appear with information. Text describing initialization states to press the 'E' button on the keypad. See Figure 4-3 of the XINIX manual. It is recommended to read Section 4.0 of this manual if not familiar with XINIX operation.

1. Press 'E' on the keypad and the main menu will appear. When selecting an option from the main menu always press 'E' to enter the value. The choices for the option will appear at the bottom of the screen.
2. Select '9' for Process Page.
3. Turn the key from LOCK to PROG.
4. Using the arrow keys scroll down the menu until TEST RUN is highlighted. The options for this parameter are displayed at the bottom of the screen. Select '2' for YES and press 'E'.
5. Turn the key to LOCK.
6. Press the MENU key to return to the main menu.

The XINIX is now in test mode and all deposition sequences will be performed with the exception that the gun filament will not turn on. The deposition rate will be simulated. The test run is a wise step to perform when a new process is being used or the operator is unsure of the entered program parameters. Otherwise, the test run can be skipped.

7. Program the Layer parameters. Select PROGRAMS 1 AND 2, PROGRAMS 3 AND 4, etc. Place the key in PROG position. Refer to the XINIX operator manual, Section

4.3 for a description of each parameter. The SOURCE option has two parameters: Source and Hearth. Since there is only one source in the system, this parameter is always 1. The hearth is another term for crucible. There are four crucibles to choose from. The SENSOR option is always 1-1 since there is one head and one crystal. Once programming is completed, turn the key to LOCK. If thickness monitoring is performed with the crystal set Thickness 2 to the target thickness. If thickness monitoring is performed with the optical monitor set Thickness 2 to a value greater than the estimated physical thickness. If Thickness 2 is reached before the optical monitor setpoint, the deposition will end.

8. Program the Master Film File parameters. Select FILMS (1 – 60). Refer to Section 4.3.3 of the XINIX manual for a description of each parameter. The NPS (Next Program Start) Code is assigned to each film number specifying the condition to advance to the next film. Thickness monitoring with the crystal or optical monitor will determine the type of code used. Notice that an asterisk is in front of the first film to start. The position of the asterisk and the size of the process are determined by two things: the Process select knob on the E.B. Gun Rotation and the Input Port setup on the Process Page (option '9' of the main menu). It may be necessary to redefine the Process number size and start position by placing the key in PROG and selecting Input Port. Once in the Input Port screen the cursor keys do not function. Use the 'E' key to scroll down.

Thickness Monitoring with Crystal Monitor

Record all required parameters in the CHA Operation Log book. The cooling water and main switch on the high voltage power supply must be on. Insure that the O_2 bottle valve, valve between the bottle and regulator, and valve behind the evaporator are open if O_2 is to be used. Place the GAS 1 switches in AUTO for each layer that requires a gas backfill. Adjustment of the gas MFC will be necessary to obtain the desired backfill pressure. As a guideline, a gas flow of 3.2 sccm gives a backfill pressure of 2×10^{-5} torr. Place the FIN THICK MON SELECT to XTAL for every layer that will be deposited. A copy of the operating procedures from the CHA Manual starts on the following page and

covers all other necessary steps. Manual operation of the Beam Sweep Control is necessary. Turn on the Beam Sweep Control before the start of the deposition and after the high voltage is present. High voltage should be set at 10 kV. The CYCLE COMPLETE switch must be on the final deposited layer to correctly terminate the deposition process. If a TEST RUN is being performed, all sequences will be activated with the exception of filament current. No more than six layers can be deposited for a given process selection. If more than six layers are required, the additional layers can be assigned to another process selection number, and a new run can be performed after selecting the new process selection. An example follows for such a situation:

Programs 1 and 2 are used to give a 10-layer film stack. NPS Code 4 indicates to start the next layer at the end of the current layer. NPS Code 0 indicates Final Layer. By placing the Process Select switch to 1 and Cycle Complete switch to 6, the first six layers will be deposited and Process 1 will be completed. Place the Process Select switch to 2 and the Cycle Complete switch to 4, cycle the AUTO-STANDBY-VENT switch on the Auto-Tech II controller from AUTO to STANDBY then back to AUTO to reset the system (always inspect the Master File page to insure the asterisk is adjacent to the desired process). Process 2 will begin.

Process Selection #1

01 1-4

02 2-4

03 1-4

04 2-4

05 1-4

06 2-0

Process Selection #2

11 1-4

12 2-4

13 1-4

14 2-0

If a TEST RUN is done and all sequences are correct, return to Process Page and select NO for TEST RUN then reset the system by depressing the Auto-Tech II switch to STANDBY, wait for gate valve to close, then switch to START to reset the system. The ready light will illuminate after approximately ten seconds if the chamber pressure is less than 2×10^{-6} torr, and e-beam high voltage will be present. Insure that Beam Sweep Control is on. Press the green START button on the XINIX to start deposition if chamber pressure is below 2×10^{-6} and deposition has not started. Otherwise, wait until chamber pressure setpoint is reach where deposition will start automatically. After deposition is complete, return the MFC (gas mass flow controller) to zero, return gas select switches to middle position, close the gas valve behind the evaporator, turn the HV Control key to off, turn the EB Power key CCW to remove line voltage, vent the system, remove samples, use the vacuum cleaner to remove any loose debris in the chamber, replenish evaporating material in crucibles if necessary, press the XINIX T/F button to read the crystal frequency. A frequency less that 5.83 MHz requires a crystal change. Turn off the XINIX. Place the chamber under vacuum, turn off the breaker on the side of the SR-10 high voltage power supply, and shut off the cooling water.

Thickness Monitoring with Optical Monitor

The Eddy LCM-10 Optical Monitor must be programmed before deposition. The reflective response of films during growth must be known to properly determine the End of Deposition (EOD) condition. Film growth software is available to model the reflectivity vs. thickness to predict responses.

Press the Power button at the lower left corner of the monitor. The main menu will appear on the LCD screen. Refer to the LMC-10 Instruction Manual for additional information. The following options will appear:

Program #
Layer #
Remote Start

Create Program
Modify Program
Chip Count
Maintenance
Material File

Each of the eight options can be highlighted using the Up and Down Arrows just to the right of the Power button. Material Files have been built:

Material 1	MgF2	(magnesium fluoride)
Material 2	HfO2	(hafnium oxide)
Material 3	SiO2	(silicon dioxide)
Material 4	Si	(silicon)

To view, modify or add a file, move the cursor with the Arrow buttons to MATERIAL FILE, press the INC+ or DEC– button to select the file number then press the ENTER button. Using the Cursor, INC+, DEC-, and ENTER buttons makes the necessary changes to the file. Press the EXIT key when finished. It is necessary to program I/O PORT A for every material such that OUTPUT 7 is ON. This action activates Relay 7 and shorts pins 8 and 9 as monitoring starts, and removes an EOD (end of deposition) signal to the XINIX. When the quarter wave setpoint is reached, Relay 7 de-activates opening pins 8 and 9 thereby placing an EOD signal to the XINIX.

Creating a program requires that the program number be selected first. Highlight the Program # and change the number using the INC+ or DEC- buttons. DO NOT press the ENTER button. Doing so will start the optical monitor. If the ENTER button is accidentally pressed, depress the STOP button. Scroll down to CREATE PROGRAM and press ENTER. The following text will appear:

Chip Temp: 100 C

Using INC+ or DEC- place the Chip Temp to 84 C. The reason for this is because a chip heater is not used and a 130 ohm resister has been placed in pins 1 and 3 of the chip plug on the back of the instrument to simulate a chip temperature of 84 C. Entering 84 C will prevent error messages during program execution. Now the screen should read

Chip Temp: 84 C

Press ENTER

Overshoot: 2%

This value is the amount of overshoot from the quarter wave setpoint. INC+ or DEC- this value.

Press ENTER

Noise Rejection Level: 5

This level is in LM (light monitor) units. If the noise level is above the set value, an error message is generated. The value 5 is a good value for this system.

Press ENTER

# of Layers: 1

Use INC+ or DEC- to set the number of layers to be deposited.

Press ENTER

Chip Drop: NO

Press ENTER (chip drop not used)

Quarter Waves: 1.00

INC+ or DEC- the quarter wave setpoint. The minimum value is 1.00.

Press ENTER

Initial Signal: 500

This is the initial LM signal. The scaled range is from 1-1000. The value 500 is the midpoint and provides the largest dynamic range for high and low swings.

Press ENTER

Monochromater: 500

The design wavelength in nanometers is displayed. Use INC+ or DEC- to set.

Press ENTER

Material: 1

INC+ or DEC- this number. The material file must exist

Press ENTER

If more than one layer is being programmed, the menu will repeat for the next layer. Press EXIT when programming is completed.

To MODIFY a program, select the program number, scroll down to MODIFY PROGRAM and press ENTER. The same menu will appear.

To run the CHA using the optical monitor the following steps MUST be performed before evaporation. Once these steps have been satisfied, proceed with evaporation similar to Crystal Monitoring procedures:

1. Select the desired program from the main menu of the Eddy LCM-10 optical monitor.
2. Place FIN THICK MON SELECT to OPT for each layer to be deposited.
3. The XINIX NPS Code in the Master File for every film must be 6 (external input) to accept the EOD external signal from the LCM-10.
4. Thickness 2 for each film program must be greater than the physical thickness of the film. If Thickness 2 is reached before the quarter wave setpoint, the shutter will close. Choose a Thickness 2 value much greater than the calculated physical thickness of the film.
5. Press the START button on the LCM-10. The optical monitor must be in run mode prior to starting the deposition. If automatic deposition is started before the optical monitor is in run or monitoring mode, the EOD signal will be present at the start of deposition and immediately terminate the layer deposition.

Once in run mode, a real time plot of the reflectivity will appear on the screen. It should initially be a straight line. Proceed with automatic deposition similar to Crystal Monitoring. The main difference between the two monitoring schemes is the EOD signal.

Safety Precautions

During operation of the CHA, safety precautions must be followed to prevent personal injury and/or damage to equipment. If running any controller in Manual mode, be aware of all the consequences involved with such a situation. Always use Auto mode when possible. Allow ten minute cooling periods at 0% power for crucibles before crucible

changes or shutdowns. Use adequate ramp and soak periods during material heating. Do not override any interlocks. If a problem arises, shut the system down and seek help.