Thin Film Deposition Using The
Denton Explorer-14 E-Beam Evaporator

University of Notre Dame
Department of Electrical Engineering
Nanofabrication Facility

This user manual is not to be removed from 247. A downloaded copy can be obtained from the web at the following link:

http://www.nd.edu/~ee/ndnf/

or contact Keith Darr for a copy of this manual.

Purpose

The Denton Explorer® 14 Thin Film Coating System, located in the University of Notre Dame's Nanofabrication Facility (247 Fitzpatrick Hall), is used to deposit high quality thin films for use in semiconductor manufacturing. The Explorer-14 is a fully automated vacuum deposition system equipped with an XYZ Piezo Nano-Positioner stage for use in precision, photolithography free, nano-scale patterning. This system is capable of MFC controlled reactive depositions, as well as PID regulated heating.

Reference Documents

Denton Vacuum Explorer® 14, Operating Manual
   - Denton Vacuum, LLC, 2005
Model TT-8 Electron Beam Source Power Supply, Instruction Manual
   - Telemark, 2004
Operating Manual, XTC/C XTC/2 Thin Film Deposition Controller
   - Inficon, 2001
Electron Beam Source XY Sweep with Memory Module, Instruction Manual
   - Telemark, 1998

Additional Equipment Required

None

Materials Required

Substrate to accept film deposition

Protective Equipment Required

Safety glasses
Latex Gloves

Engineering and/or Administrative Controls

Only authorized users may operate this piece of equipment

Training

To obtain training on this machine, please contact Keith Darr (office 221 Cushing, phone 631-5497, email kdarr@nd.edu)

Problems

For problems, clarification of procedures, or general information pertaining to this machine please contact one of the following personnel.

Keith Darr 631-5497   **kdarr@nd.edu**
Mike Thomas 631-7493   **Thomas.20@nd.edu**
Mark Richmond 631-6478 **Richmond.7@nd.edu**

In Case of Emergency, Please Contact Notre Dame Security at

911

MSDS's can be located in the EE Department office or in Room 244 near the door.

Table of Contents

Page   Contents

Keith Darr
Rev 1.2
10/31/2008

Authorized Users List

Name	Email	Advisor	Date

List of Components

1. Digital Piezo Controller/XYZ Stage interface
2. Inficon XTC/2 quartz crystal rate controller
3. TT-8 Electron Beam Power Supply
4. Cryo Torr-8 cryogenic pump and compressor
5. Varian DS402 rotary vane pump
6. Maxtek MPI-16, crucible indexer
7. Telemark TFI-270 series (six pockets, 40 cm^3/pocket), electron beam gun
8. Chamber #1 [30" (high) x 14" (wide) x 14" (deep)]
9. Chamber #2 [18" (high) x 14" (wide) x 14" (deep)]
10. Inficon BPG-400 Wide-Range Pressure Sensor
11. Dell Computer and Flat Panel Monitor
12. MKS Mass Flow Controller
13. GE programmable logic controller
14. GE Cimplicity HMI software
15. Telemark X-Y Memory sweep control

Standby Conditions

1. On Telemark TT-8 controller
   a. Key in the OFF position
   b. (Remote – Loc – Hand) switch in REMOTE position
   c. Bias switch in ON position
2. On Telemark XY sweep controller
   a. (Control – Sweep Select) switch in CONTROL position
   b. Power switch in ON position
   c. Joystick in midpoint
   d. (Spiral – Triangle – Manual) switch in MANUAL
   e. (Manual – Auto) switch in MANUAL
   f. Sweep Select (1 2 3 4) switch in position 1
   g. All 4 Channel's Mode (Spiral – Manual) switches in MANUAL
3. Software
   a. Left in Overview screen
   b. System Control in Auto
   c. Under E-Beam Control Screen (must be in Manual operation mode to verify)
      i. Control Mode #1 in XTC ON (green)

Software Overview

1. Six main software screen comprise the ProcessPro Software package
   a. Login
      i. ProcessPro logo in the center
      ii. Start up screen upon computer power up
      iii. No login is needed at this time
   b. Overview
      i. This screen is comprises of the system layout and valve diagram.
      ii. Most process parameters are available from this screen.
   c. Recipe
      i. This screen show the recipe tree
      ii. It is used to access build dialog boxes for creating automated processing recipes.
   d. Alarm View
      i. Allows acknowledgement of system errors
   e. Alarm Recovery
      i. Shows a list of recovered alarms
   f. Datalogger
      i. Opens MS Access
      ii. Most process parameters are stored Access in real time during an automated recipe execution. This data can be extracted for manipulation on an external computer.

Opening the Chamber and Pumping the System Down

1. Verify that the system in "Auto" on the "Overview" screen.
2. Click on the "Recipe" button at the bottom of the software screen
3. Click on "Edit/Create" under "Master Recipe"
4. Click on "Open" under "File Options"
   a. File selection window will open
5. Select "AutoVent.dat" and click open
   a. File selection window will close and "AutoVent.dat" should be listed in the "Master Sequence List"
   b. "C:\CIMPLICITY\Integrity_36\Master_Recipe\AutoVent.dat" should be listed in the "Master Recipe File Name" box
6. Click on the "Download" button
   a. The gate valve will close at this time and make a noise
7. Click on "Close" to close the "Master Recipe Builder" window
8. Select the "Overview" screen by pressing the appropriate button at the bottom of the screen
9. Click on the "Start" button at the top left of the "Overview" screen
   a. The "AutoVent" recipe will start to run
   b. The vent valve will be actuated automatically
   c. The doors will open after approximately 2 minutes time

10. You may insert your substrate at this time
11. After you are complete with inserting you substrate close and latch the doors
12. Click on the "Recipe" button at the bottom of the software screen
13. Click on "Edit/Create" under "Master Recipe"
14. Click on "Open" under "File Options"
   a. File selection window will open
15. Select "AutoPump.dat" and click open
   a. File selection window will close and "AutoPump.dat" should be listed in the "Master Sequence List"
   b. "C:\CIMPLICITY\Integrity_36\Master_Recipe\AutoPump.dat" should be listed in the "Master Recipe File Name" box
16. Click on the "Download" button
17. Click on "Close" to close the "Master Recipe Builder" window
18. Select the "Overview" screen by pressing the appropriate button at the bottom of the screen
19. Click on the "Start" button at the top left of the "Overview" screen
   a. The "AutoPump" recipe will start to run

Beam Positioning and Sweep Setup

1. Ensure that the key on the sweep controller is in the off position
2. Enter the overview screen on the computer
3. Change the operation mode of the software from "Auto" to "Manual"
   a. Click on the Manual button on the top left of the screen
      i. "Manual" button will turn green and "Auto" button will turn gray
4. Click on the gray "E-Beam Status & Control" tool bar
   a. The "E-Beam Control" window will open up
5. In the "E-Beam Control" window
   a. Make certain that the following conditions exist
      i. All four "System Enable" buttons are off – grayed out
         1. If any are green, click on them to turn them off
      ii. "Control Mode #1" in XTC – green
   b. Click on the number next in the "Crucible Control #1" box
      i. Enter the desired crucible to select the proper material
      ii. Press the enter button
6. On the sweep controller, turn the power ON
7. Set the (Control – Sweep Select) switch to the control position
8. Set the joystick to the midpoint position
9. Set the (Spiral – Triangle – Manual) switch to the manual position
10. Adjust the joystick so that the position indication LEDs are centered
11. Turn the key to the ON position
12. On the software, in the E-beam control window,
   a. Enable system power by clicking the ON button
      i. Button should turn green
13. Wait 30 seconds

        a. This allows time for the air interlock switch to close

14. Click on the "Reset" button in the "E-Beam Control" window
   a. A series of LED will illuminate on the HV & Emission control module
      i. Air Cab, Vac, Tank, Aux1 under the "High Voltage" section
      ii. HVAC, Water, Aux2 under the "Source 1" section
   b. This clears and initializes all hardware interlocks
   c. If any of these LED do not stay lit, the system will not allow the high voltage power supply from energizing. Contact lab staff.

15. Enable "High Voltage" power by clicking the "ON" button next to "HV Pwr" in the "E-Beam Control" window
   a. Button should turn green
   b. The LCD should read around -8.50 DC Kilovolts on the "High Voltage Control" module

16. Press the "CLEAR / UP / RESET" button on the Inficon XTC/2 controller
   a. This will reset the XTC/2

17. Press the "4 / MPWR" button on the Inficon XTC/2 controller
   a. This will put the XTC/2 into manual power control
   b. Ensure that the output power on the XTC/2 reads 00.0%
      i. If it does not, press the "Reset" button again followed by the "MPWR" button and verify that the output power reads 00.0%
   c. Emission control will be able to be increased by the hand controller at this time

18. While looking through the chamber view-port, slowly start to increase the emission current until there is a very light beam visible in the crucible.
   a. If the beam is visible with no increase of emission current power, then do not increase it at this time.
      i. You only need to be able to see the beam at this time.
   b. Keep the emission current very low.
   c. You only want to be able to see the beam at this time.
   d. Do not cause the source to start to get hot enough to evaporate.
   e. Do not exceed 30 millimaperes as read on the "Source 1" LCD.

19. If only one sweep pattern is desired, then all position and beam patterning can be performed using the left control section.
      i. The recipe will disregard any channel selection and default to the settings on the Control section
      ii. Typically a single sweep pattern will suffice for similar materials
   b. Center the beam in the source by moving the joystick around slowly
   c. Switch the mode switch (Spiral – Triangle – Manual) to the desired pattern
      i. Adjust the beam pattern using the Lateral and Longitudinal controls for the desired sweep pattern
         1. The "Mod Amp" is only used for the "Spiral" mode
            a. It is used to adjust the depth of the spirals collapse
   d. The control section is now programmed

20. If more than one sweep pattern is desired for multiple deposition material
   a. Ensure that the Sweep Select section's (Manual – Auto) switch, located on the far right bottom, is in the manual position
      i. If it is in "Auto," change it to "Manual"
   b. Rotate the (1-2-3-4 Select) knob to the desired channel position
   c. Switch to the desired channels mode switch (Spiral - __ - Manual) to "Manual"
      i. This is a 3-position switch. The center position is the "Triangle" mode; however, there is no space for labeling.
   d. Change the (Control – Sweep Select) switch to "Sweep Select"
   e. The beam position can now be adjusted by using the "Lat" and "Long Pos" knobs
      i. Adjust the beam pattern using the Lateral and Longitudinal controls for the desired sweep pattern
   f. Switch the mode switch (Spiral – Triangle – Manual) to the desired pattern
      i. Adjust the beam pattern using the Lateral and Longitudinal controls for the desired sweep pattern
         1. The "Mod Amp" is only used for the "Spiral" mode
            a. It is used to adjust the depth of the spirals collapse
   g. If a different material is to be used and a separate channel's pattern is desired, the beam must be turned off prior to changing the crucible.
      i. Press the XTC/2 handheld button in to turn the beam off
      ii. Press the "CLEAR / UP / RESET" button on the Inficon XTC/2 controller
         1. This will reset the XTC/2
      iii. Press the "4 / MPWR" button on the Inficon XTC/2 controller
         1. This will put the XTC/2 into manual power control
         2. Ensure that the output power on the XTC/2 reads 00.0%
            a. If it does not, press the "Reset" button again followed by the "MPWR" button and verify that the output power reads 00.0%
      iv. In the "E-Beam Control" window
         1. Click on the number next in the "Crucible Control #1" box
            a. Enter the desired crucible to select the proper material
            b. Hit the enter button
               i. The crucible will rotate to the desired material position
      v. Change the "1-2-3-4 Select" knob to the desired channel and repeat the setup procedure for this channel
21. Turn gun current and high voltage off after beam position and sweep patterning setup is complete
   a. In the "E-Beam Control" window toggle the "Emission", "HV Pwr" and "System Power" buttons off
22. Return the system to "Auto" in the "Overview" screen

Recipe Creation and Downloading

Note: A multi-step recipe will be built with this procedure. You may add or omit portions of this procedure to accommodate your desired process.

1. Enter the "Recipe" screen
   a. Click on the button at the bottom of the screen labeled "Recipe"
2. To create a XTC controlled process recipe
   a. Click on "Edit/Create" under "Termination Configuration"
      i. The "XTC Configuration" window will open.
   b. Enter appropriate process parameters
      i. "Rise Time 1", "Soak Power 1", and "Soak Time 1" combined with "Rise Time 2", "Soak Power 2", and "Soak Time 2" will define a pre-deposition power profile.
         1. This type of profile can be use to help remove oxide build up on the surface of the source material and to ensure a proper melt has occurred prior to the actual deposition.
         2. The following chart demonstrates an example of a pre-deposition power profile with the following parameter settings:
            a. Rise Time 1 = 00:45
            b. Soak Power 1 = 35.0 %
            c. Soak Time 1 = 1:00
            d. Rise Time 2 = 00:30
            e. Soak Power 2 = 40.0 %
            f. Soak Time 2 = 00:30

      g. At the completion of "Soak Time 2" the process will go into rate control as defined in the "Deposition Rate (A/s)" box
      3. "Tooling Factor 1" and "Tooling Factor 2" should be set to **87** if using the dome holder in chamber #1 (the lower chamber)
      4. "Final Thickness" should be entered to desired final thickness

5. "Density (g/cc)" and "Z-Ratio" should be set for applicable material
    a. Chart is available on computer desktop for density and Z-ratio
6. "Sensor" = 1
7. "Source" = 1
8. "Crucible" = 0
    a. Does not need set in an XTC recipe it will be defined in the "Deposition Configuration" recipe
9. "Control Gain" = 0.001
10. "Control TC" = 0.1
11. "Control DT" = 0.1
12. "Max Power" = 50 %
13. "Sample" = 1
14. "Hold Time" = 00:00
15. "New Rate", "Rate Ramp Time", and "Idle Ramp" do not need defined

ii. Once all parameter have been set, "Click Save As"
1. A dialog box will open where the file name can be entered.
2. The file name must take the form:
    a. "XTC###.DAT"
        i. Where ### are three numbers (000-999)
        ii. Please select a set of numbers that are not in use unless you are redefining the parameters in a known recipe.
        iii. Remember this file name; you will need to reference it in future recipe definitions.
    b. A dialog box will open stating:
        i. "File will be saved as …"
            1. Click "OK"

3. To create a "Deposition Configuration" recipe
    a. Click on "Edit/Create" above "Deposition"
        i. The "Deposition Configuration" window will open
        ii. You will be able to set process criteria in this window
            1. "Process Heat"
            2. "Minimum Vacuum Required"
                a. "Y" & value less than "1e-4 "or "N"
            3. "XTC FILE" (You only need to enter the 3 digits)
            4. "Crucible Number" (1-6)
            5. "Sweep Pattern Number" (1-4)
                a. Default is channel 1, if sweep controller is in manual
            6. Process gas flow
                a. Fixed "SCCM" or "PID Pressure "in Torr
                    i. 0 – 100 SCCM
            7. "Nanopositioner XYZ"
                a. In um
                b. X&Y axis 0 – 100.000um

c. Z axis 0 – 10.000um
iii. Click "Save As"
1. Dialog window will open
2. Name must be 7 or less characters with no special characters
3. Click "Save"
a. Box will open indicating "File will be saved as …"
i. Click "OK"
4. To create an "Auto Heat Configuration" recipe
a. On "Recipe" main screen, click "Edit/Create" above "Heat Subroutine"
i. "Auto Heat Configuration" dialog box will open
ii. Enter desired heat in "Heat Setpt" box
1. Value in degrees Centigrade
2. Value must be less than 130°C or damage to crystal monitor may occur
iii. Enter "Soak Time" in appropriate box
1. The heat subroutine will run for this time after it reaches the desired set point.
iv. Click "Yes" or "No" selection box if minimum vacuum required prior to heat subroutine begins
1. If yes is selected, enter desired pressure in Torr
a. Example
i. "1e-4"
Note: PID settings are only available in manual operation

v. Click "Save As"
1. Dialog box will open where file name may be entered
a. File name must be seven characters or less with no special characters.
2. Click "Save"
a. Dialog box will open indicating "File will be saved as…"
b. Click "OK"
5. To create a "Master Recipe"
a. On main "Recipe" screen click "Edit/Create" under "Master Recipe"
b. "Master Recipe Builder" dialog box will open
i. A single or mulitstep sequence can be built by using the "Master Recipe Builder."
ii. A master recipe can be built that has "Auto Pump", "Auto Heat", "Auto Deposition", or "Auto Regen" (for cyro maintenance) subroutines or a combination of any or all sequence types.
c. If you need to build a "Master Recipe"
i. Click on the pull down arrow next to the "Sequence Type" box.
1. Click on the desired sequence type name on the pull down list.
a. If the sequence type that you need is showing in the "Sequence Type" box, you will need to click on the

sequence type name so that the "User Defined Sequences" list is populated.

  ii. Click on the pull down arrow next to the "User Defined Sequences" box.
    1. Click on the name of the desired subroutine recipe that you require for you process.
      a. The user defined sequence file name should appear under the "Master Sequence List."
    2. Click on the "Add" button, which is below the "User Defined Sequences" box.
      a. Insert can be used to add a subroutine between two previously existing recipes in the master sequence list.
      b. Replace will replace the selected existing subroutine in the master sequence list.
  iii. To add another subroutine to the "Master Recipe" being built
    1. Click in the white space just below the file name that most recently was added to the master sequence list.
      a. The blue selection bar will move to the next sequence order position in the master sequence list.
    2. Perform the steps required to add a subroutine to the master sequence list
  iv. When all desired subroutines are added to the master sequence list
    1. Click on the "Save As" button
      a. The save new master dialog box will open
      b. Enter a master recipe file name
      c. Click on the "Save" button
        i. A dialog box will open indicating "User chooses to save file as: …"
          1. Click on "OK"
        ii. If the file name exists already, you will be prompted to replace the file.
      d. The master recipe file name will be displayed in the top box on the "Master Recipe Builder"
    2. Click on the "Download" button.
      a. This sends the sequence to the PLC for processing
      b. If the first step to the master recipe is an "AutoVent" recipe, the gate valve will automatically close now. A loud sound should be expected, this is the gate valve operating.
    3. Click on the "Close" button at the bottom left of the "Master Recipe Builder"
    4. Return to the "Overview" screen by clicking on the appropriately labeled button at the bottom of the screen.
6. Execute downloaded "Master" recipe from the "Overview" by clicking on the "Start" button
  a. Button should turn green and processing will run through completion.
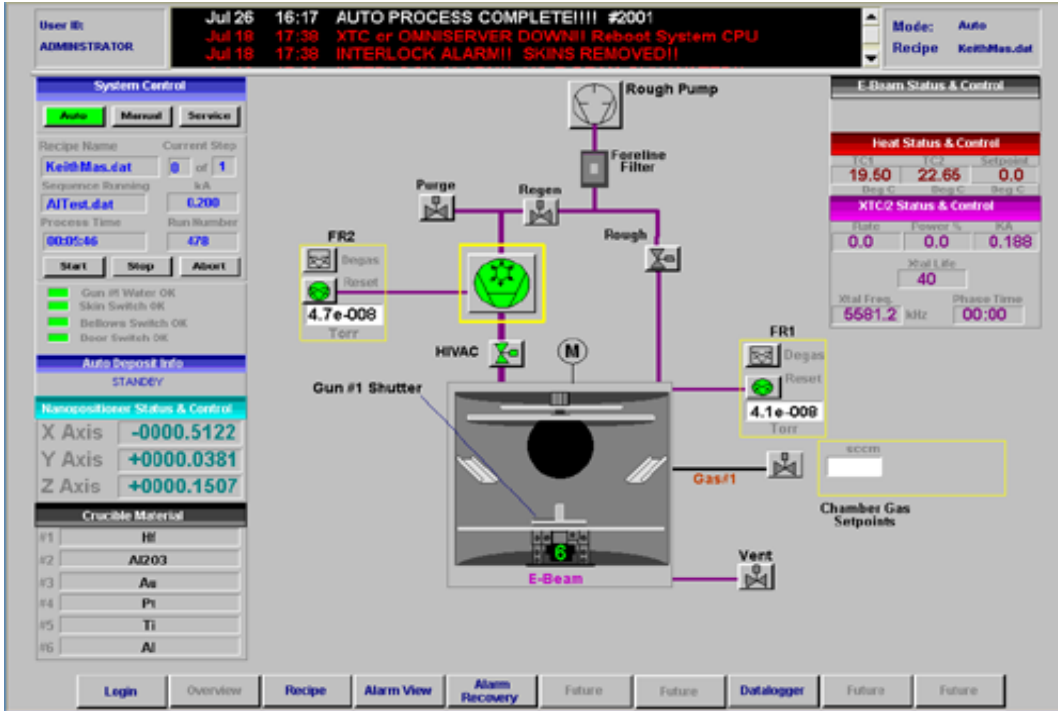
Figure 1
Overview Software Screen
      Main screen for process information and recipe execution

Telemark TT-8/10/15 Controller
High Voltage and Current Control

XY Sweep Controller (with Memory Module)
Sweep Control and Beam Positioning

Figure 2

Inficon XTC/2 Deposition Controller
Thickness Monitoring and Process Recipe Automation
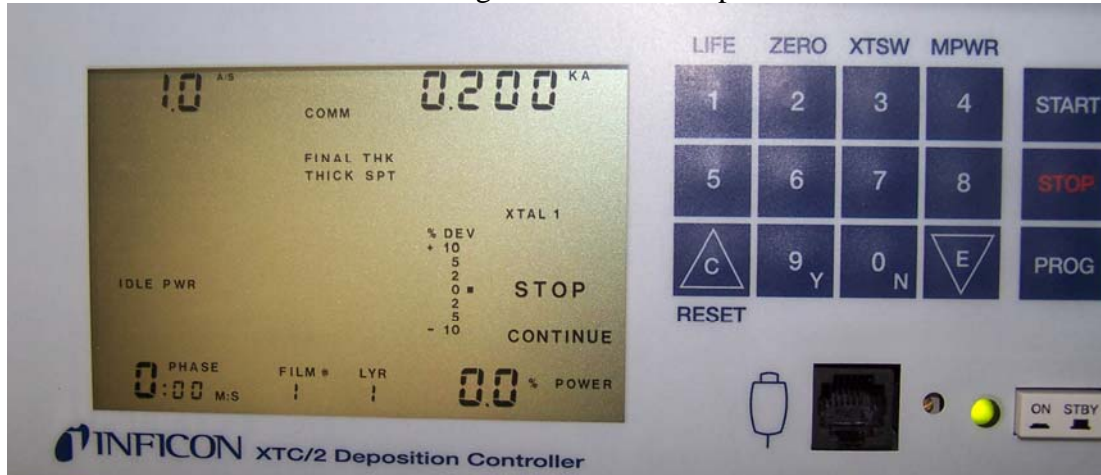

Figure 3

    LIFE - Displays the percent of crystal life used.
    ZERO - Clears the displayed thickness.
    XTSW - Changes the active crystal.
    MPWR - Places the unit in manual power control or rate control mode
    START - Initiates the sequencing.
    STOP - Halts the operation.
    PROG - Toggles the display between the program and operate screens.
    ON/STBY - Switches power of the instrument between On and Standby
    Green LED - Indicates that the unit is set to On
    ENTER / DOWN - Cursor control and decreases power in MPWR
    0/N – Zero or No - also enters communication set up if held during power up
    9/Y – Nine or Yes - used when in program mode
    CLEAR / UP / RESET - Cursor control, raises power in MPWR, and resets unit
    DIGITS (0-9) - if the nine key is held during power up – LCD segment test