Chapter 6.31

Ion Beam Deposition System (4” and 6”)

(iondep - 584)

1.0 Title

Iondep – Ion Beam Deposition System.

2.0 Purpose

Iondep is an ion beam based deposition system. It can be used in Ion Beam Sputtering (IBS) mode or Ion Beam Assisted Deposition (IBAD) mode. This tool is specifically designed to deposit thin Silicon Carbide or Carbon films at low temperatures (below 450°C) by sputtering with or without assist. It is capable of depositing on 4” and 6” wafers at various temperatures and tilt angles.

3.0 Scope

This document provides operational procedures for iondep, recipe selection, and user-level troubleshooting.

4.0 Applicable Documents

Revision History

4.1 Operators Reference Manual Binder (located by the machine and also stored as .pdf files on iondep computer)

4.2 MSDS information for argon, 10% silane in argon, and 10% methane in argon

4.3 Vendor Information: Process Materials, Inc.

http://www.processmaterials.com

5625 Brisa St. Suite A
Livermore, California 94550
Phone: (925) 245-9626

5.0 Definitions & Process Terminology

5.1 IBS (Ion Beam Sputtering) Mode: Sputter deposition process that uses an ion beam to sputter a target.

5.2 IBAD (Ion Beam Assisted Deposition) Mode: Deposition process that uses a separate, independent ion source (assist) with the sputtering ion source. The assist source is used for ion bombardment during film growth which can alter the properties of the thin film.

5.3 Angle of Incidence: The angle between the substrate normal and the angle at which atoms arrive at the substrate. The deposition process has been optimized for an angle of incidence of 50 degrees. Please contact staff for modification of this angle.

5.4 PC Control Panel: Allows user to pump, vent, select and monitor process.

5.5 Deposition Controller: Indicates crystal health, deposition rate, and time remaining for 16 cm Ion Source deposition. The controller also opens/closes the shutter.

5.6 Process Chamber Components

5.6.1 Shutter: Prevents sputtering onto substrate when 16cm Source is ramping up.
5.6.2 **Heater Box:** Contains four quartz heating lamps and is capable of heating substrate surface to approximately 400°C.

5.6.3 **Substrate Holder:** Secures wafer to heating/rotating chuck via three spring clips. Maximum rotation is 5 rpm.

5.6.4 **Target Carousel:** Holder for the target material and capable of holding three targets. Currently available target materials are silicon carbide (SiC), silicon, and carbon. Process Materials INC is the vendor for the targets.

5.6.5 **16 cm Ion Source:** Ion beam used to sputter the target material for deposition on to the wafer. Argon is the currently available gas.

5.6.6 **RF Neutralizer:** Neutralizer for 16 cm source.

5.6.7 **16 cm Ion Source Controller:** Loads, saves, and stores programs for the 16 cm ion source.

5.6.8 **Mark II Ion Source:** Secondary ion beam source for etching (cleaning wafer surface) and ion bombardment (alter material properties). Argon, 10% silane in argon, and 10% methane in argon are the currently available gases.

5.6.9 **Mark II HO Controller:** PC system that updates Mark II setpoints.

5.6.10 **HCES (Hollow Cathode Electron Source):** Gas source attached to Mark II.

5.6.11 **Crystal Health Indicator:** Reads deposition rate and crystal health.

6.0 **Safety**

6.1 **Use nitrite gloves at all times when handling components that go in the chamber or when cleaning the chamber.** This protects you from the particles in the chamber as well as the tool from body oils that can outgas or damage the pumps.

6.2 **High Voltage Hazard:** Iondep utilizes a high power source for the operation of its ion sources and heater. Do not touch the high power electrical parts behind the service panels.

6.3 **Strong Light Hazard:** The plasma emits strong light. Do not look straight into the plasma for a long period of time.

6.4 **Burn Hazard:** The deposition chamber is usually quite warm after a deposition process. In particular, the Heater Box, Mark II source, HCES, and Target Holder are usually hot after deposition. Because the process runs under vacuum, it takes a while for everything to cool down. Do not vent the chamber until the PC reads a substrate temperature below 100°C. There is an interlock for this but **DO NOT** try to bypass this step to save time.

6.5 **Do not leave the vacuum system until you are certain the chamber is pumping down properly.**

6.6 **Do not use N2 gun to clean the iondep.** Use a vacuum hose to prevent particles from being blown around.

6.7 **Please contact the Marvell NanoLab staff if new gases or target materials need to be used. ** **DO NOT** experiment with new materials without permission.

7.0 **Statistical/Process Data**

7.1 **16 cm Source Recipes**

7.1.1 **Program #1**

7.1.1.1 Beam (Current, Voltage): 500 mA, 1000 V

7.1.1.2 Accel. (Current, Voltage): 17 mA, 175 V

7.1.1.3 RF Source (Forward Power): 400 W
7.1.4 RF Neutral (Emission Current): 625 mA
7.1.5 RF Neutral (Forward Power): 64 W

Note: These settings are known to yield stoichiometric SiC. With an angle of incidence of 50 degrees the deposition rate is approximately 0.4 um/hour.

7.2 Mark II Assist Source Recipes

7.2.1 Program # 1

7.2.1.1 $V_{anode} = 150$ V
7.2.1.2 $I_{anode} = 5$ A
7.2.1.3 Gas 1 (Argon)
7.2.1.4 Start Source Gas Flow = 8.5 sccm
7.2.1.5 HCES Flow = 4 sccm

Note: This high energy recipe is typically used to etching/cleaning the substrate surface.

7.2.2 Program # 2

7.2.2.1 $V_{anode} = 60$ V
7.2.2.2 $I_{anode} = 1.5$ A
7.2.2.3 Gas 1 (Argon)
7.2.2.4 Start Source Gas Flow = 6 sccm
7.2.2.5 HCES Flow = 3 sccm

Note: This recipe is used for moderate ion bombardment.

8.0 Available Process, Gases, Process Notes

Materials: The only materials allowed in the chamber are silicon carbide (SiC), silicon (Si), silicon dioxide (SiO$_2$), and silicon nitride (Si$_3$N$_4$). No other materials are allowed. Materials such as polymers may outgass and damage the pumps or contaminate the chamber. **DO NOT put new materials into the chamber without permission from Marvell NanoLab staff.**

9.0 Operating Procedure

9.1 Enable iondep with WAND, if software process screen does not show, double click on the Welcome icon on the Windows Desktop.

9.2 From the process screen (Figure 11.3) vent chamber by pressing the Vent button in the lower left of the monitor.

9.3 If the chamber is cool, wearing gloves, use a Techni-cloth with some isopropyl alcohol (IPA) and wipe the substrate holder, door seal, heater box, and floor of the chamber to check for debris. Particulates in the chamber can degrade film quality. If the chamber is clean and no particulates or dust are wiped up, continue past 9.4 Cleaning Procedures.

9.4 Cleaning Procedures

9.4.1 If heater box and substrate holder are cool, use a Techni-cloth with IPA and wipe down. Also, wipe down the top of the shutter.

9.4.2 If there are a lot of particulates use the vacuum cleaner located next to the iondep tool and vacuum the inside of the chamber.
9.4.3 If aluminum foil on the walls of the chamber is flaking, report a faults report notifying equipment staff in charge of the tool to change out the foil.

9.5 Check if the Mark II is appropriately covered or uncovered with foil.

9.5.1 If using the tool in IBS mode, use aluminum foil to cover the Mark II opening as well as the HCES source opening. Sputtering deposits can damage these components if they are not in use and are left uncovered. If covering Mark II & HCES, check to make sure shutter can close. This is done by pressing the shutter button on the Mark II controller.

9.5.2 If using the tool in IBAD mode, remove any foil that is covering the Mark II or the HCES opening.

9.6 If the desired process requires the substrate holder to rotate, it is a good idea to also check rotation before pumping down the system. This is done by pressing the rotate button on the engineer screen. Do not set the rotation above 5 rpm. If no rotation is observed, refer to the troubleshooting guidelines.

9.7 Load wafer onto the substrate holder and secure it in place with the spring clips.

9.8 Close the shutter by pressing the shutter button on the deposition controller.

9.9 Close the chamber door and lock by turning all three knobs.

9.10 Pump down the system pressing Pump on the process screen.

9.11 Monitor the pumping and ensure that the chamber crosses over to Hi-Vac and that the pressure is below 5.00E-6 Torr.

   Note: The cross over chamber pressure for the roughing pump is 100 mTorr.

9.12 Once the system is in Hi-Vac, turn on the 16 cm ion source controller. Otherwise, your process will not start.

9.13 From the recipe screen, load the desired recipe.

9.14 Recipe Selection

9.14.1 Please speak with superuser or staff before creating/modifying a recipe.

9.14.2 To load a recipe, press the load recipe button at the bottom of the recipe screen.

9.14.3 To save a recipe, press the save recipe button at the bottom of the recipe screen.

9.14.4 Overview Recipe Steps

9.14.4.1 Heat (Step 1) – Used as a heat ramping and hold step. The maximum temperature allowed is 400°C.

9.14.4.2 Etch (Step 6) – Used to turn on Mark II for a cleaning/etching of substrate surface.

9.14.4.3 Deposit (Step 8) – Used to turn on 16 cm ion source for deposition and Mark II for assist bombardment.

9.14.4.4 Delay (Step 9) – Used as a hold step for purging of ion sources.

9.14.4.5 Cool (Step 14) – Used to cool the substrate holder with high gas flows to 100°C after deposition. This step is optional.

9.14.4.6 End (Step 15) – Ends the deposition and is the last step of the recipe.

9.14.4.7 Skip – Skips to the next process step.

   Note: Please keep the appropriate step numbers when creating recipes. Ex. Heat step is always step #1.
9.14.5 Changing The Deposition Time

9.14.5.1 On the deposition controller press **program** button.

9.14.5.2 Scroll to the appropriate program number

9.14.5.3 Press the > button to access program

9.14.5.4 Modify the thickness to change the time. Please note that 1 Angstroms = 1 seconds. For example: 3.6 kAngstroms = 3600 seconds.

9.14.5.5 Press the < button 2X to exit program.

9.15 Open the liquid nitrogen (LN) valve for pump cooling.

9.15.1 Manually open valve on the LN dewar.

9.15.2 Press the **LN valve** icon on the vacuum screen.

9.16 From the process screen, press the **Start** button to begin the process.

9.17 Should a major failure occur or if the process needs to be halted immediately, press the Process Abort button on the process screen. The abort will shut down all process related equipment (vacuum equipment will remain running).

9.18 If there is a minor error, pressing the **Hold** button will leave the process sequence at the current step until the **Continue** button is pressed. If **Hold** is pressed during the actual material deposition, it will be paused after the material is deposited and the shutter is closed.

9.19 During the Deposit Step (#8) of the recipe, there is a 15 minute purge delay for the 16 cm ion source. Once the purge is complete, it is a good idea to monitor the 16cm source controller settings and the Mark II controller settings and ensure that the sources start up without problems.

9.19.1 Check that the 16 cm ion source controller reads the correct beam current (default is 500 mA). If not, abort the recipe and report a fault. This may mean that there is a short in the discharge chamber.

9.19.2 Check that the plasma is a purple or magenta color. If not, abort recipe and report a fault. Any discoloring of the plasma could mean that the chamber is contaminated.

9.19.3 Check that the gas flow rates are reaching the set points. If not, abort recipe and report a fault.

9.19.4 In IBAD mode, if Mark II source current reaches 15 A and stays there for more than three seconds, immediately hit abort and refer to the troubleshooting guidelines.

9.20 After process is complete, turn off the 16 cm ion beam controller, close the LN flow, vent the chamber, and retrieve the wafer.

9.21 Use caution when retrieving and loading samples. **NOTE:** Do not vent the chamber until the PC reads a substrate temperature below 100°C. There is an interlock for this but do not try to bypass this hold step to save time. This could lead to severe burns or oxidation of the chamber components.

9.22 When done using the iondep, pump down the chamber for the next user. Do not leave until the chamber reaches Hi-Vac and pressure is below 5.00E-6 Torr.

9.23 Disable the iondep with WAND.
10.0 Troubleshooting Guidelines

10.1 Hi-Vac gate takes a long time to open or close when either pumping down or venting system.

10.1.1 If trying to vent from Hi-Vac, pump down the system again by pressing Pump on the process screen and try again.

10.1.2 If trying to pump down from a vented system, vent the system again by pressing Vent on the process screen and try again.

10.1.3 If problem persists, leave the system in its stable state (pumped or vented) and report a fault to alert staff immediately.

10.2 Mark II Source current reaches 15 A limit and stays there for more than 3 seconds.

10.2.1 Abort process by pressing the Abort button on the process screen and reset the alarms with the Alarm Reset button located on the top right.

10.2.2 Refer to the flowchart (Figure 11.5) to select the appropriate Mark II start flow.

10.2.3 If problem persists, report a fault to alert staff.

10.3 16 cm ion source reads a lower beam current than the recipe setting.

10.3.1 Abort process by pressing the Abort button on the process screen and reset the alarms with the Alarm Reset button located on the top right.

10.3.2 Leave the system pumped down

10.3.3 Report a fault for bead blasting of the ceramic dome inside of the 16cm ion source.

10.4 16 cm ion source controller is not starting and a beam is not visible

10.4.1 Abort process by pressing the Abort button on the process screen and reset the alarms with the Alarm Reset button located on the top right.

10.4.2 Do not attempt to run recipe again

10.4.3 Report a fault for staff to look at feedthrough connectors behind the 16 cm ion source.

10.5 The substrate heater is not reaching the setpoint temperature.

10.5.1 Abort process by pressing the Abort button on the process screen and reset the alarms with the Alarm Reset button located on the top right.

10.5.2 Try to run the recipe again.

10.5.3 If problem persists, abort recipe and leave system pumped down.

10.5.4 Report a fault.

10.6 The substrate holder is not rotating when pressing rotate on the engineering screen.

10.6.1 Report a fault.
11.0 Figures & Schematics

Figure 11.1 - Iondep Interior Overview
Figure 11.2 - Schematic of the Various Control Panels of the Iondep System
Figure 11.3 - Schematic of Process Screen
Figure 11.4 - Schematic of Vacuum Screen
Figure 11.5 - Process Flow For Selecting Appropriate Mark II Recipe
(From Veeco’s Mark II HO Controller Technical Manual)
12.0 Appendices

12.1 System Shut Down Procedure for Staff Only: Used only when total powering down of the system is needed.

12.1.1 From a Hi-Vac chamber state press the Pump button to go into manual mode.

12.1.2 From the Vacuum Screen press the following buttons in this order to start shut down of turbo pumps
   - 12.1.2.1 IG-1 (Turns off ion gauge)
   - 12.1.2.2 Hi-Vac (closes valve)
   - 12.1.2.3 Turbo (begins deceleration of turbos)

12.1.3 Wait for approximately 15 minutes for both turbo pumps to turn off. Confirm that turbos have spun down by looking at LEDs on the turbo controllers.

12.1.4 From the Vacuum Screen press the foreline valve to close it

12.1.5 Go to back of machine (behind the deposition chamber) the vent the pumps by turning t-valve

12.1.6 Turn off the main breaker located at the back of the machine near the gas cylinders

12.1.7 Shut down the PC

12.1.8 Turn off all power switches of controllers (Deposition, Mark II, 16 cm Ion source, RF neutralizer) except for the turbos.

12.1.9 Turn of all breakers on the side of the controller panel.

12.1.10 To power up do the reverse of this procedure.

12.2 Vacuum Setup Default Values (for Staff Only) - DO NOT CHANGE THESE VALUES!

12.2.1 Atm. Setpoint = 760 Torr

12.2.2 Roughing Line Ready = 200 mTorr

12.2.3 High Vacuum Crossover Setpoint = 110 mTorr

12.2.4 Heater Enable Setpoint = 5E-4 Torr

12.2.5 Heater Disable Setpoint = 5E-3 Torr

12.2.6 High Temperature Alarm Set = 500°C