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| **Document:** Vapor Phase Decomposition Droplet Scanner Standard Operating Procedure | **Revision:** A | **Release Date:** |
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# **Equipment Purpose**

* 1. The VPD droplet scanner is designed to use an acidic scanning solution to extract contaminants from a silicon wafer so that the contaminants may later be measured through use of an ICP-MS.

# **Equipment Specifications**



# **Cleanliness Standard**

* 1. TBD

# **Processing Capabilities**

# **Becoming a User**

# **Safety**

* 1. This device uses an acidic scanning solution that contains HF. Ensure that all proper protocols are followed for acid & HF handling. If the contact is made with HF, immediately stop using the machine follow the necessary procedure for an HF spill.
  2. This device has open, moving wires. Before use, ensure that all wires are free to move and that they will not cause damage when the machine is in motion.
  3. This machine has multiple cooling ducts and fan systems to ensure proper cooling of all electronic components.
     1. Ensure that each cooling duct is not blocked before using the machine.
     2. If liquid of any kind, including the scanning liquid, comes in contact with the metal frame of the machine, immediately turn off power to the machine and unplug it from all outlets. Ensure that the spill is properly reported and handled. Before resuming use, ensure that all electronic components are free from moisture and corrosion.
  4. During and following use, the machine’s motors will become hot to the touch. Take precautions to ensure that this heat does not cause harm to the user or to lab equipment.

# **Required Equipment**

* 1. 4 or 6 inch silicon wafer. Wafer pieces are not able to be processed at this time.
  2. Appropriate size wafer holder for the wafer being scanned.
  3. Sanitized 1mL polypropylene plastic syringe.
  4. Sanitized cuvette for storage of sample droplet.
  5. Pre-mixed scanning solution.

# **Operating Procedure**

Before beginning, familiarize yourself with the safety considerations outlined in section 6.

* 1. If the scan head is not in the back left corner of the scan plate, follow abort procedure (section 13) to avoid damaging the machine.
  2. Perform an overall inspection of the machine. Ensure that all wires are free to move and will not catch during machine operation. Ensure that all air ducts are free from debris and moisture. Ensure that the scan motor cable is properly seated in the scan motor cable guide.
  3. Align the syringe plunger holder with the zero mark on the syringe, either by using the provided alignment mark on the side of the scan head or by inserting a syringe into the head, depressing the plunger holder as much as possible, and carefully removing the syringe to avoid moving the plunger holder.
  4. Find the correct size wafer holder for your sample and insert it into the scan base, making sure that the slot in the wafer holder aligns with the corresponding slot on the scan base. Carefully insert your wafer into the slot in the wafer holder.
  5. Turn the machine on using the red switch on the right side of the machine. Depress the selection wheel to access the menu items. Rotate the wheel to select “Print from Media.” Depress the wheel again to select.
  6. Rotate the selection wheel to find the appropriate scan routine for your wafer (e.g. for a 4 inch wafer, select “4inScan.gcode”). Depress the wheel and select “Print” to begin the scan.
  7. After automatic calibration, the scanner will place the scan head over the wafer, open the plunger holder, and beep. Fill your sanitized syringe with the appropriate amount of scan solution (see section 11), and place it into the slot in the scan head, making sure that the plunger is securely seated in the plunger holder. Once finished, depress the selection dial to begin your scan.
  8. The scanner will begin the scan routine. At the end of the cycle, it will collect the scan droplet, fully open the syringe plunger for easy removal, and emit an audible beep.
  9. Once the cycle has finished and the scanner has beeped, remove the syringe from the plunger, making sure not to spill any solution from the syringe. Dispense your sample into the appropriate cuvette and seal it. Dispose of the syringe appropriately.
  10. Depress the selection dial, which will move the plunger holder to the “0” mark and move to the scan head to the back left of the scan plate. Turn the machine off using the red switch on the right side of the machine.
  11. Remove the wafer with wafer with wafer tweezers.
  12. If any solution spilled during the procedure, clean all affected parts thoroughly.

1. **Recipe Parameters**
   1. Scan Solution:

# **Definitions and Process Terminology**

* 1. Bed Leveling Knobs: The bed leveling knobs are positioned at the four corners of the scan plate. They serve to adjust the compression of the scan plate spacers.
  2. Cuvette Holder: Small, cylindrical plastic piece that can be inserted into the scan base. The cuvette holder has a hole through its center so that the cuvette may be inserted into it.
  3. Cuvette: A clear plastic container for holding the scan droplet.
  4. End Stop: Physical switches on the X & Y axes that tell the system where the ends of the
  5. ICP-MS: Inductively coupled plasma mass spectrometry. The technique used to quantify the composition of contaminants in the scan droplet.
  6. Interface Screen: The LCD panel at the bottom right of the machine. Used to interact with the machine and select a scanning protocol.
  7. Pinion Gear: The plastic gear mounted to the front side of the scan head. It is responsible for transferring the rotational motion of the scan motor to the plunger holder.
  8. Plunger Holder: The long, sliding plastic component that wraps around the end of the syringe’s plunger so that it may be moved up and down via the pinion gear and scan motor.
  9. Scan Base: The large plastic piece that is mounted to the scan plate and has cylindrical holes for the cuvette holders(s) and wafer holder.
  10. Scan Droplet: The small volume of scan solution dragged by the syringe which dissolves and collects wafer contaminants.
  11. Scan Head: The plastic assembly bolted to the x-axis gantry. The scan head is connected to the syringe, plunger holder, scan motor, and pinion gear.
  12. Scan Motor Wire Guide: This white plastic guide is attached to the top Delrin roller wheel on the left side of the x-axis gantry. It ensures that the scan motor does not become tangled, caught, or otherwise damaged as the scan head moves.
  13. Scan Motor: The silver and black rectangular prism bolted into the scan head. This motor is responsible for moving the syringe’s plunger by moving the pinion gear.
  14. Scan Plate Spacers: Four cylinders with holes through their center points for countersunk bolts. These spacers keep the scan plate even and level across it’s face.
  15. Scan Plate: The large square metal base that the scan base is bolted to.
  16. Scan Solution: The acidic solution that makes up the scan droplet. This solution is used to dissolve contaminants in the wafer.
  17. Selection Dial: The round knob at the bottom right below the interface screen.
  18. Syringe: This system is designed to use 1mL HSW® Norm-Ject® Luer-Slip Syringes, Air-Tite. This syringe press fits into the scan head, and the syringe plunger fits into the plunger holder. They can be easily identified by their blue-green plunger and clear main body.
  19. VPD: Vapor phase decomposition, an established technique for contamination analysis of wafers.
  20. Wafer Holder: Cylindrical insert for the scan plate upon which the silicon wafer to be scanned rests.

# **Process Data**

* 1. 4-inch (100mm) Wafer
     1. Scan Duration: ~20 minutes.
     2. Scan Radius: From radius 65.0mm to 5.0mm
     3. Scan Droplet Volume: 0.05mL
  2. 6-inch (150mm) Wafer
     1. Scan Duration: ~53 minutes.
     2. Scan Area: From radius 40.0 to 4.0.
     3. Scan Droplet Volume: 0.05mL

# **Troubleshooting**

|  |  |  |
| --- | --- | --- |
| **Symptom** | **Issue** | **Resolution** |
| The loaded syringe won’t fit into the scan head. | Failure to align the plunger holder before scan. | Turn the machine off. Align the mark on the plunger holder with the mark on the scan head body. Alternatively, place the syringe with the plunger fully depressed into the scan head. Once the plunger is fully aligned at 0mL, remove the syringe. Be careful not to move the plunger holder. |
| The printer won’t move after starting a scan routine or after instructing printer to move | Disconnected wires | Ensure that all four (4) motor wires are fully connected.  Ensure that all three (3) end stop cables are fully connected.  Cables are labeled for convenience with yellow tags at the cable ends. |
| There are no files under “Print from Media” | SD read error or disconnected SD card | Above “Print from Media,” press “Change Media” to re-read the SD card. Recheck “Print from Media.”  If there are still no visible files, turn off the scanner. Unplug the microSD card from the front of the scanner, remove it, and replace it. Ensure that it fully ‘clicks’ in. Recheck “Print from Media.” |
| The scan droplet is consistently lost in the same spot on the wafer | Uneven scan surface. | First, ensure that the wafer holder is fully seated and flat in the scan base. Verify that the syringe is fully seated in the scan head.  If problems persist, verify the adjustment of the eccentric nuts, particularly on the scan head and y-axis.  If issues continue, level the system by following the leveling procedure outlines in “Maintenance” |
| The system won’t turn on. | Loose power cable. | Over time, the power cable can become loose. Make sure the red switch is set to off (O) before checking that both the system side and wall socke side of the power cable is fully seated. |

# **Abort Procedure**

If, for any reason, the machine must be interrupted during a regular scan cycle, follow this procedure to prevent damage to the system.

* 1. Turn the machine off using the red power switch on the right side of the machine. Then, unplug the power cord.
  2. Clean up any scanning solution that may be left behind. Remove the syringe from the scan head.
  3. Move the syringe plunger holder down to the zero point. You will be unable to do this after the machine is powered on.
  4. Once the system has been cleaned, ensure that the red switch is in the OFF (O) position before plugging in the power cable. Once the cable is fully seated, you may turn the system on.
  5. Finally, it is important to ensure that the printhead will not encounter any obstacles when running the next scan procedure. To do so, use the machine’s interface (Press knob > Motion > Move Axis > Move Z > Move 10mm > Rotate knob to move) to raise the Z-axis well above any obstacles on the XY plane.

# **Maintenance**

To ensure smooth operation of the system, a few regular maintenance items should be conducted. This section will divide these maintenance items by the frequency that they should be performed.

**Before performing any maintenance, ensure that the machine has been turned off and is unplugged unless otherwise noted.**

* 1. XY Belts
     1. Belt Tension: The X & Y belts of the system help maintain the dimensional consistency of the scanner. Over time, these belts will loosen and the machine’s ability to move in the XY plane will be hampered. To tighten the belts
        1. Locate and access the belt tensioner at one end of the axis on which you want to tighten the belt.
        2. Use the appropriate Allen key to loosen the belt tensioner. There are two screws on the X-axis and four on the Y-axis of the machine.
        3. Once the tensioner is loose on the frame, hold the frame with one hand and with moderate strength pull the tensioner in the direction that will tighten the belts (away from the moving part).
        4. Hold the tensioner in its far-back position, let go of the frame, and, using the Allen key used earlier, tighten the bolts so that the tensioner is tight. Do not overtighten these bolts.
        5. After tensioning the system, perform a visual inspection of the T-nuts behind the bolts. Ensure that they are facing upwards, perpendicular to the length of the metal frame. If they are not, the nut will not be secured against the frame and the belt will quietly lose tension. See (15.2) for a visual guide to proper installation.
     2. Belts are a consumable part. After extended periods of use, they will show signs of wear (cracking, tearing, fraying). Replace and reattach belts as needed. Follow the above procedure to ensure proper belt tension.
  2. Delrin V-Slot Wheels
     1. The moving axes of this printer connect to the frame via rolling Delrin wheels.
        1. Each side of the x-axis gantry has three (3) wheels. The scan head has another three (3) wheels. Below the moving y-axis plate are four (4) additional wheels.
     2. If scan head wobble, grinding, skipping, excess wear, inaccurate XY motion (after ensuring proper belt tension) Wheel tightness to the frame can be adjusted using the eccentric nuts on the machine. Each side of the x-axis gantry has one (1) eccentric nut on the inside rolling wheel. The scan head has one (1) nut on the bottom wheel. The right side of the rolling y-axis gantry has two (2) eccentric nuts. These nuts can be identified by their larger size and hexagonal shape. See (15.1) for a photo example. To adjust the nuts:
        1. Obtain the proper size wrench (10mm).
        2. Identify the axis and eccentric nut that need to be adjusted.
        3. Using the wrench, rotate the nut. To check tightness, hold the axis in place and attempt to rotate the Delrin wheel. The wheel should rotate in place with a slight amount of force needed to keep the axis in place.
        4. Once you are satisfied with the ability of the wheel to rotate, check the other wheels of the axis as they will have been affected by this adjustment.
        5. Finally, verify overall axis motion. The axis should move freely without excess resistance but should be tight enough to be free of wobble, tilt, or rotation.
     3. These wheels are consumable and will wear over time. Symptoms of worn wheels include visible wear on axes and frame of printer, sagging x-axis gantry, inconsistent or inaccurate axis motion, or significant differences noted in the size or shape of one of the wheels. Before replacing wheels, ensure that the eccentric nuts have been adjusted properly.
  3. Z-Axis Threaded Rod
     1. The Z-axis threaded rod is located behind the left vertical frame of the machine. It is responsible for powering the vertical movement of the scan head.
     2. Since the rod has metal-on-metal contact, it will require periodic lubrication to prevent excess wear. To lubricate the axis:
        1. Remove any old lubricant by thoroughly cleaning the rod using isopropyl alcohol. Use the machine’s controls (Press knob > Motion > Move Axis > Move Z > Move 10mm > Rotate knob to move) to spin and move the axis for thorough cleaning. Be careful not to raise the Z-axis too high to prevent snagging or catching of wires.
        2. Apply an appropriate amount of lubricant to the length of the rod. Use the machine again to move the axis up and down multiple times to ensure even distribution across the rod.
        3. If using non-Teflon lubricant, wipe off excess lubricant to leave behind only a thin layer.
  4. Scan Plate & Scan Plate Springs
     1. Currently, the system uses springs to level the scan plate, which in turn levels the scan bed, the wafer holder and wafer. Ensuring that the scan plate is level relative to the syringe tip is essential for reliable operation of the system. If the plate is not level, the distance from the syringe tip to the wafer will vary across the scan, and the tip may lose contact with the drop or dig into the wafer or wafer holder. To level the scan plate:

(**Note:** Be advised that if the bed is particularly poorly leveled at the start of this process, the syringe tip may grind and press into the wafer holder plate. If there is concern that this may be an issue, tighten all four (4) knobs down before beginning the scanning process).

* + - 1. Obtain either a 0.1mm feeler gauge or a blank piece of printer paper. You will also need a syringe and the 4in wafer holder. Insert the wafer holder into the scan base.
      2. Navigate to the “Print from media” menu on the scanner and select “levelScanner.gcode” The scanner will automatically calibrate before moving to the center of the wafer holder. After the beep, insert the syringe and press the selection dial to begin the leveling process.
      3. The syringe tip will lower down to Z = 0. In sequence, the syringe tip will be slowly moved towards the four corners of the scan plate. The user will level each point, then the system will return to each point to check that the level was executed properly.
      4. To level a point, slide the feeler gauge or portion of paper underneath the tip of the syringe. Adjust the respective leveling knob so that there is a slight amount of resistance when moving the gauge or paper. Remember that that when looking straight down over the scanner, rotating the knobs clockwise will tighten them, increasing the gap between the syringe and surface. To decrease the distance, turn the knobs counterclockwise.
      5. Once you are satisfied with the point, press the selection knob to move to the next point.
      6. After you have leveled and re-leveled all four points, the scan holder will open the plunger for easy removal of the syringe. Remove the syringe and press the selection knob. Your leveling is now complete.
  1. Scan Head (Syringe Holder, Plunger Holder, Pinion Gear, Scan Motor)
     1. The plunger holder should not need regular maintenance or replacement.
     2. Periodically check the rack gears on the plunger holder for degradation with use. If wear is noted, replace with a new plunger holder.
     3. The pinion gear may wear with time. If any wear is noted, remove the gear, and replace with a new gear. To check for wear:
        1. Remove the syringe plunger holder and inspect the gear teeth. They should be straight, with no crushing, warping, twists, or other defects.
        2. To check the connection between the pinion gear and scan motor, run a scan cycle. Observe the interface between shaft of the scan motor and the pinion gear. If there is slipping between the two surfaces, the gear is worn and should be replaced.
     4. Periodically check all screws and bolts for proper fit and tightness. If bolts are loose, tighten them to finger tightness. **Do not over tighten.**
     5. Periodically check the scan motor cable for wear, with particular emphasis on the bottom portion of the cable, as it comes in contact with the scan motor wire holder during scanning. Replace as needed.

# **Appendices, Figures & Schematics**

* 1. Y-Axis Eccentric Nut

A close up of a screw

Description automatically generated

* 1. T-Nut Proper & Improper Installation
     1. Proper T-Nut Installation

A metal object with a screw

Description automatically generated

* + 1. Improper T-Nut Installation

A close up of a screw

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# **Revision Block**

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| --- | --- | --- | --- |
| **Revision** | **Date** | **Description of Change** | **Author** |
| 1 | 8/31/23 | Initial creation of SOP. | Trevor Jehl |