

Installation and Operation of an Inductively-Coupled Plasma (ICP) Etcher

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ABSTRACT

This project follows the design of the full timeline of an equipment installation in a microelectronics cleanroom, from developing an understanding of the tool through preparation of facilities, installation of the tool, and setup for use. The tool installed is a Plasmatherm Apex SLR Inductively-Coupled Plasma (ICP) Etcher manufactured by Advanced Vacuum. This tool was purchased by an RIT professor for ICP etching on III-V substrates, a new capability for the RIT SMFL. Installed additionally are the auxiliary equipment units, including two chillers, a Gas Reactor Column (GRC), and a roughing pump. The operation of the main tool for processing is analyzed as well as the roles that the auxiliary equipment play in operation of the system as a whole. Facilities needs such as electricity, process gases, cooling water, and exhaust are assessed, and their installation described. The process of decommissioning a Perkin-Elmer 2400 sputtering tool and the movement and refurbishing of a Consolidated Vacuum Corporation (CVC) Metal Evaporator are also detailed as necessary steps in preparing the RIT SMFL for the installation of the new ICP Etcher.

Keywords: Facilities, Maintenance, Installation, Tool, Etch

1. INTRODUCTION

Microelectronic processing techniques and equipment must be adapted and improved to make smaller features of higher quality as devices continue to shrink in size, in accordance with Moore's Law. Etching processes are moving away from wet etch to dry etch in order to support these demands. An ICP etcher and its auxiliary equipment were purchased on a grant for research performed by Dr. Jing Yang and her researchers. Adding this tool to the RIT SMFL represents an expansion of capabilities, as there is no tool currently specialized to dry etch on III-V substrates.

2. THEORY

ICP etching is a reactive ion etch method that utilizes a combination of physical and chemical etching [1]. Process gases are flowed through a chamber separate from the process chamber that is surrounded by a coil. This coil is powered by radio frequency (RF) power, generating an electric field. The process gases are broken into ions and radicals, accelerated through this chamber, and a spark at the electrode creates the process plasma. The plasma bombards the surface of the wafer, removing material from unprotected sections of the wafer. By manipulating input variables such as the etch gas chemistries, RF table bias, and process time, results can be controlled for output variables such as selectivity, etch rate, anisotropy, and uniformity [2].

The ICP etcher model purchased is a Plasmatherm Apex SLR Inductively-Coupled Plasma (ICP) Etcher manufactured by Advanced Vacuum. The tool is supported by four pieces of auxiliary equipment – a roughing pump, a large water-cooled chiller, a small thermal fluid chiller, and a gas reactor cabinet (GRC). The rough pump is used to create a rough vacuum for the process chamber, which helps to accelerate the plasma perpendicular to the wafer for improved anisotropy. The large chiller provides a cooling water loop separate from the main building facilities line, controlled for more exacting resistivity standards. The small chiller provides thermal fluid to the ICP etcher electrode for more efficient cooling. The GRC is used for gas abatement to remove harmful chemical species from the vented etch byproducts through creation of ionic salts.



Figure 1: Advanced Vacuum Apex SLR ICP Etcher in the RIT SMFL



Figure 2: ICP Etcher auxiliary equipment. From left to right: Large chiller, small chiller, roughing pump, GRC. Not to scale.

3. DETERMINING TOOL LOCATION

The first step in the tool installation was to determine the location where the tool would reside. Measurements of the tool and auxiliary equipment were taken, and clearances for use and maintenance were noted. Three spots were surveyed before settling on the final location. The first option was to use an empty space in the metal bay where the tool had been temporarily placed until it could be installed. The benefits of using this space were that, if everything fit, no other tools would need to be moved to take their space, and the tool itself would not need to be moved either. However, this spot did not have service aisle space available behind it, as that side of the metal bay is directly adjacent to the gowning area. To put all of the auxiliary equipment into the cleanroom would increase noise and heat in the area, and there was also no way to arrange all of the pieces to fit properly.

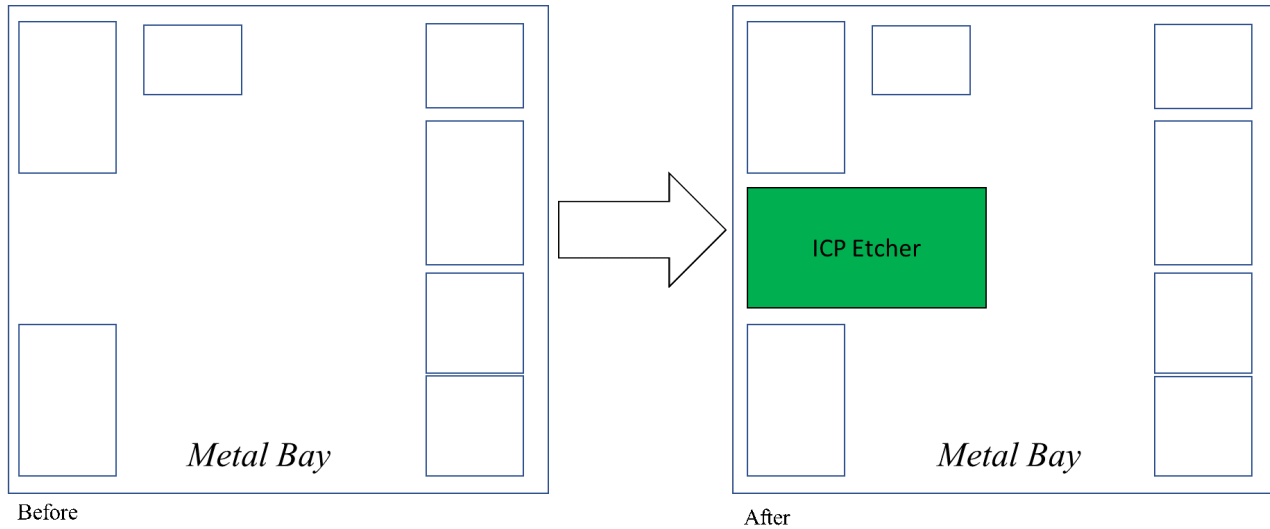


Figure 3: Option 1 for tool location

The second option was use the space currently occupied by the PE 4400 sputtering system in the dry etch bay. This would require the PE 2400 in the metal bay to be decommissioned and the PE 4400 to be moved from the dry etch bay to the previous site of the PE 2400 in the metal bay before installation work started. This option was desirable as the tool would be adjacent to the LAM 4600, another RIE tool, which would concentrate hazardous gas lines into only one area of the SMFL. Although using this location would have been beneficial to lab safety from a hazardous gases standpoint, issues arose when tool measurements were compared. The PE 4400 was significantly wider than the PE 2400, and would not fit into the PE 2400 location in the metal bay. Additionally, although there was some service aisle space available behind the proposed tool location, not all of the pieces of auxiliary equipment would be able to fit without blocking electrical panels or the doorway.

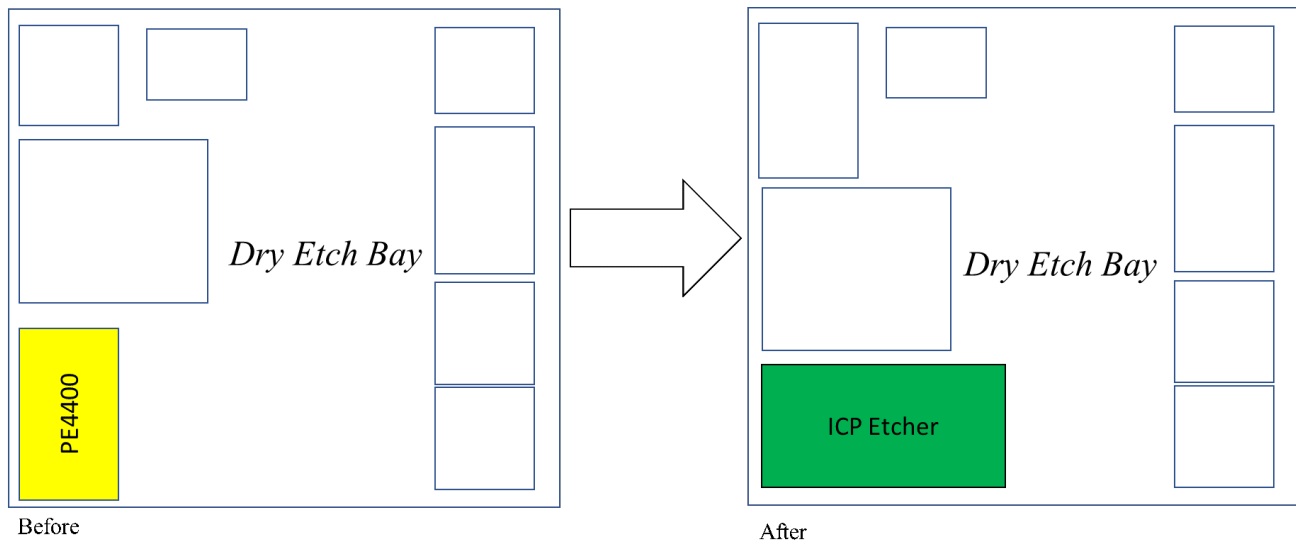


Figure 4: Option 2 for tool location

The final option was to decommission the PE 2400 sputtering, move the CVC evaporator across the metal bay into the empty space, and then install the ICP etcher in the space that had been previously occupied by those two tools. This option ended up being selected as it was the only viable space that would have sufficient room

for all new and moved pieces of equipment. The roughing pump, small chiller, and large chiller would be placed into the service aisle, and the ICP etcher and GRC would be placed into the cleanroom.

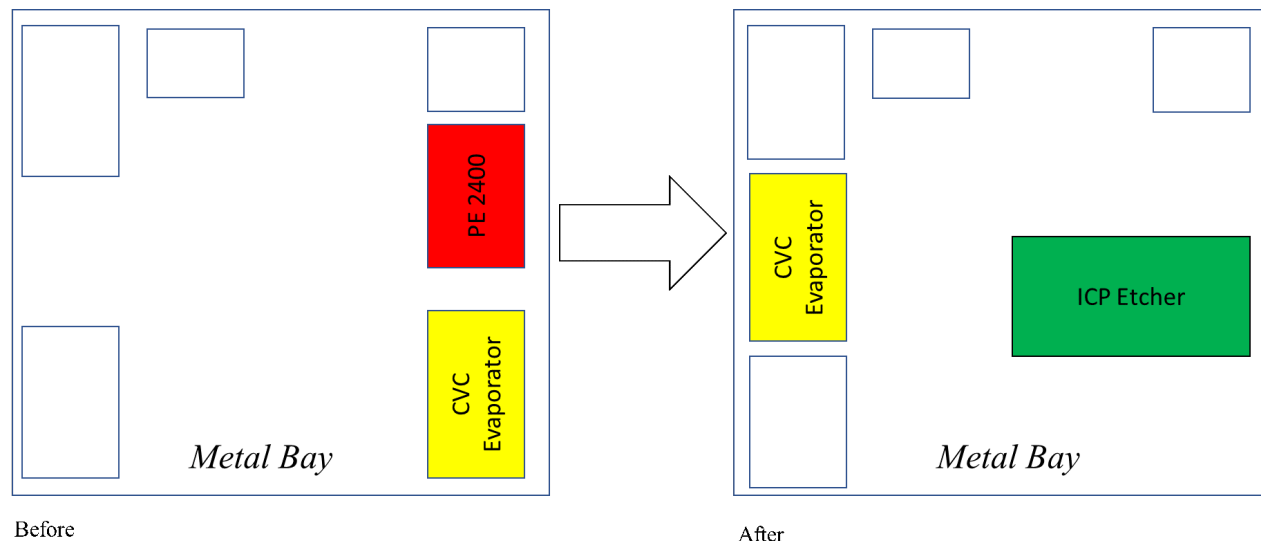


Figure 5: Option 3 for tool location

4. DECOMMISSIONING PE 2400

The PE 2400 metal sputtering system was a tool that had not seen active use in the RIT SMFL in several years. This disuse made the tool a good candidate for complete removal from the SMFL to regain cleanroom floorspace and also not need to account for tool reinstallation.



Figure 6: A PE 2400 sputtering system. <http://www.semistarcorp.com/product/perkin-elmer-2400-sputtering-system>

The first step in decommissioning the PE 2400 sputtering system was to lock-out, tag-out the main electrical disconnect box. The relevant switches were turned off in the breaker box, and removal of power from the system was confirmed by testing contacts using a multimeter in the disconnect box. Power was also shut off to the readout box on the tool that controlled flow sensors and valves. The wiring for the tool was then removed from the contactor box.

All building facilities lines needed to be disconnected from the tool. The cryogenic pump and chiller lines were disconnected, and the chiller reservoir was drained of water. All gas lines were turned off or confirmed to have already been off. Cooling water lines were shut off using the valves inside the service core. Oxygen, argon, and nitrogen lines were allowed to vent in the cleanroom as they posed no threat other than as simple asphyxiants, and they were in too small of quantities to be harmful. Cooling water lines were drained into the service core. Compressed air and vacuum connections were removed from the tool.

In preparation for moving out the PE 2400, any loose lines were tied up inside the tool and debris that had fallen under the tool was cleaned up. The tool had wheels on the frame but had been immobilized using supporting blocks. A prylever was used to remove the tool from the supporting blocks, and the tool was then wheeled out of its location.

5. MOVING AND REFURBISHING CVC EVAPORATOR

The CVC Evaporator is a tool still commonly in use in the RIT SMFL, so considerations had to be taken for a new space for the tool to be reinstalled, and the timeline in which it would be completed. It was determined that the CVC evaporator and its auxiliary equipment could fit into the empty space in the metal bay when locations were determined, so the only remaining challenge was to do the entire tool move in a reasonable amount of time.



Figure 7: The CVC Metal Evaporator

The CVC Evaporator main electrical disconnect box was locked out and tagged out, then its power was switched off inside the main circuit breaker box. A multimeter was used to confirm that tool power had been removed. Electrical lines were disconnected, followed by cooling water, nitrogen, card swipe, and compressed air lines.

Line connectors were capped to prevent damage to connectors during tool movement, and any dangling wires and tubing were tied up inside the tool. Auxiliary equipment (roughing pump and cryogenic compressor) were disconnected from the tool and removed from the location. The CVC Evaporator frame did not contain wheels, and so would have to be moved on a pallet jack. The machine frame was too low to the ground to allow the pallet jack to be run underneath, so the frame was lifted on a prylever to allow metal plates to be placed alternately under each foot of the machine until the frame was high enough off the ground to be moved on the pallet jack. The ICP Etcher was moved out of the empty space in the metal bay and the CVC Evaporator was moved into the empty space.



Figure 8: Preparing to move the CVC Evaporator

Several maintenance issues were noted with the CVC Evaporator during the move, so the timeline of reinstallation had to be weighed against the benefits of refurbishing the tool. It was concluded that it was better to sacrifice the timeline to perform preventative maintenance while the tool was already down, rather than risk failure while the tool had been put back into service. Flexible tubing lines can become brittle over time, and also clogged with debris. There were no date codes found on the tubing installed inside the CVC Evaporator, so it was unable to be determined how long it had been since the lines were replaced. The water lines were also found to contain a rusty residue. All flexible tubing lines were replaced. When the cryogenic lines were disconnected from the tool, a hissing noise was observed. Upon observation of the ends of the lines, it was found that the O-rings had damage which had allowed some helium to escape. These lines were also replaced. The machine was then hooked back up to the facilities loops in the new location.



Figure 9: A clogged cooling water line

The electrical work within the tool and within the disconnect box was outdated and worn. The contactor within the main tool disconnect box displayed severe pitting on the contacts and had to be replaced. The electrical connector on the tool showed signs of slight burning around some of the prongs, and the insulation was cracked. The connectors were replaced and the wires trimmed back to freshly stripped insulation. While the electrical lines were being surveyed for damage, it was also noted that large portions of the electrical systems did not appear to be actively supplying any parts of the tool. It was found that a large portion of the electrical work was obsolete, from a previous cooling water flow monitoring system in the tool that was no longer used. The unused electrical parts were removed from the machine, and salvaged for parts and sensors where able. The disconnect boxes for the main tool and roughing pump were reinstalled in the new tool location and rewired to the machine.

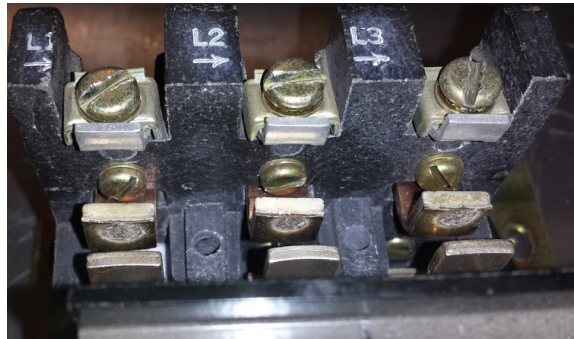


Figure 10: Disconnect box contacts exhibiting pitting



Figure 11: Electrical connector showing signs of burning (left), cracked insulation (right)



Figure 12: Some of the obsolete flow electronics/wiring



Figure 13: Refurbished and reinstalled contactor boxes

In order to fit both the roughing pump and cryogenic compressor into the very limited space in the gowning area designated for auxiliary equipment, a shelf was built from 80/20 to stack the compressor on top of another one already present. The roughing pump and compressor were then moved into position and reattached to the CVC Evaporator. The tool was then able to be brought back into service.



Figure 14: CVC Evaporator auxiliary equipment in its new location

6. ICP ETCHER INSTALLATION

Using the measurements taken during determination of the tool location, the ICP Etcher and its auxiliary equipment were moved into their final spaces. The large chiller had been supplied from inventory and needed to be refurbished prior to use. The reservoir was replaced due to previous leaking, as were the connections from the reservoir to the tool plumbing. The electrical connector was also replaced. Contactor boxes were required for the main tool, large chiller, and GRC. The small chiller and roughing pump receive their power from the main tool. The main disconnect box from the PE 2400 was able to be reused for the ICP Etcher disconnect. New contactor boxes and new conduit were run for the other auxiliary equipment needs. Switches for these electrical boxes were installed in the main breaker box, and wire was run from the breaker box to the disconnect boxes. These wires were installed to the contactors, and wires were run from the applicable contactors to their respective pieces of equipment.



Figure 15: ICP Etcher electrical work in progress

The nitrogen regulator panel in the service aisle was moved across the aisle to make room for the auxiliary equipment. New gas lines were run for this. An old hazardous gas cabinet was brought up from SMFL inventory and placed into the service aisle. Due to the extremely hazardous nature of the process gases that will be used, such as boron trichloride and chlorine, the work for the regulator panel and gas lines were sent out for quotes and will be completed by an expert from a separate entity.

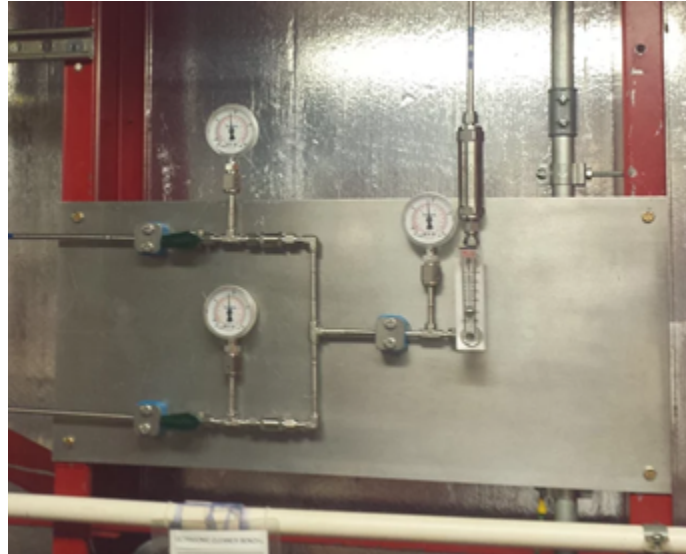


Figure 16: Refurbished nitrogen panel in new location

Exhaust lines from the GRC already installed for the LAM 4600 were observed to gain an understanding of how the installation of the GRC for the ICP Etcher would be performed. The main exhaust ducts in the interstitial area were examined for places where the new exhaust line could be connected. Then, the GRC location was surveyed to determine how to place the lines to minimize both length and number of turns. The length of each leg of the proposed line was measured, as was the circumference of the main exhaust line where the new exhaust run would be connected. These measurements were then used to send for quotes for an appropriately sized saddle connector and exhaust ductwork.



Figure 17: Surveying locations for exhaust work in the interstitial area

A manifold-based design was selected for the ICP Etcher cooling water loop. The supply line water will pump from the large chiller reservoir through a filter and polisher to meet resistivity requirements, to the supply manifold which splits into smaller lines for all cooling water inputs, to the tool and auxiliary equipment inputs. The return lines come back from the tool and auxiliary equipment to a bank of flowmeters before entering the return manifold to be consolidated for reentry into the large chiller past a flow sensor. Ball-float flowmeter models are being quoted for purchase, which must be ordered before these lines can be completed.



Figure 18: One of the manifolds designated for use in the ICP Etcher cooling water loop (left). An example of the filter and polisher setup to be used in the ICP Etcher cooling water loop (right).

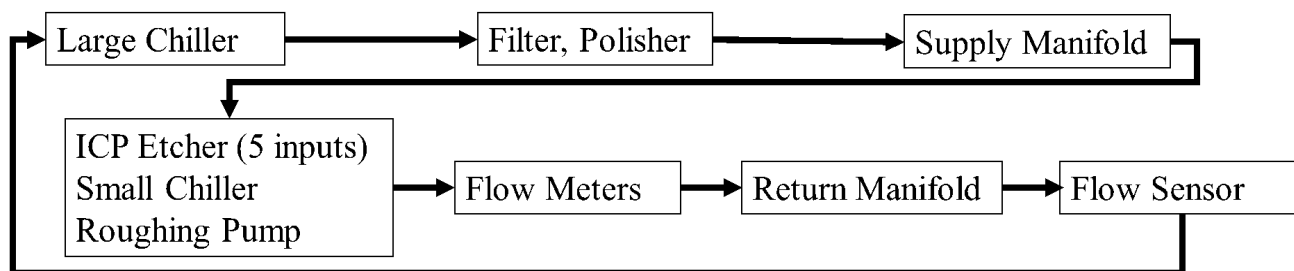


Figure 19: A flow diagram of the path of water in the cooling loop

7. FUTURE WORK

Exhaust work, cooling water loop work, and hazardous gas lines will all need to be completed before the tool can be brought up for use. All of this work is waiting on ordered parts to come in. When these installations are complete, Advanced Vacuum can be brought in to the SMFL to verify tool installation and provide preliminary etch recipes. The tool will then be ready for use.

Acknowledgments

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