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Improve Your Sputter Process by Better Water Vapor Pumping

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Improve Your Sputter Process by Better Water Vapor Pumping

A new technique helps to reduce the water present in your vacuum system.

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Key Technologies:

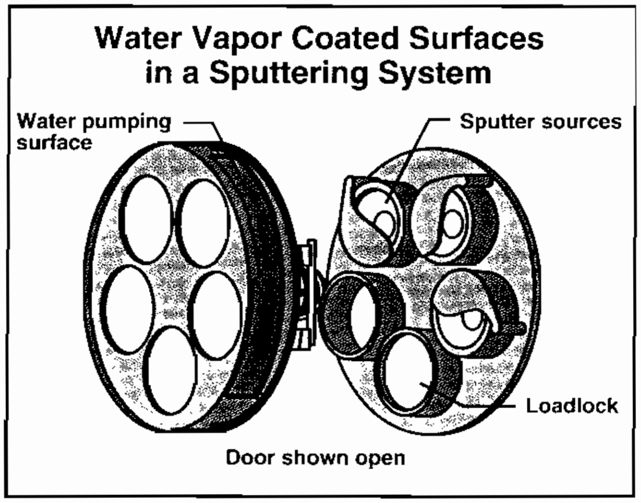
- **Sputtering**
- **Cryopumping**
- **Water Vapor Removal**

At A Glance:

The addition of a cryogenically-cooled water vapor pumping surface placed directly in a sputter process chamber dramatically improved time to achieve base pressure and film reflectivity. The system retrofit required no downtime and regular maintenance is minimal. This article discusses the significance of water in vacuum systems, the changes made to optimize water vapor pumping, and the testing done to verify system performance.

Applied Vacuum Technology
Part III: Containment

For any well-sealed vacuum system, the level of base vacuum and the time to reach the base are primarily a function of water outgassing from the surfaces of the system and the available water vapor pumping speed in the chamber. Water is a polar molecule that bonds tenaciously to any surface. Upon exposure to atmosphere, the surfaces in a vacuum system become "coated" with many tens of monolayers of water. The water evolves, or outgasses, trying to maintain an equilibrium pressure as the vacuum pumps remove the water molecules not attached to the walls. Starting at a vacuum level of several Torr or so, this desorbing water is the dominant gas load to the system. The outgassing rate and the effective water vapor pumping speed determine, in nearly all cases, the pressure-time history of the pumpdown.



1. After being exposed to atmosphere, the surfaces in a vacuum system become "coated" with many tens of monolayers of water.

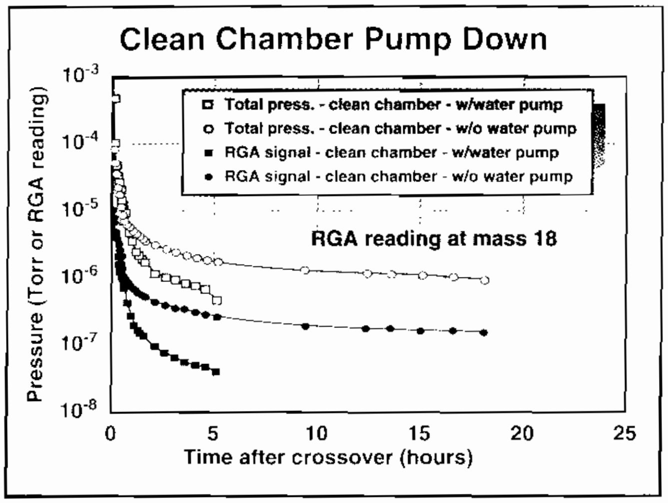
In addition to limiting pumpdown times, water, either adsorbed on the surfaces of the system or present as vapor in the vacuum space, can have deleterious effects on processes, chemistries, defects and particles. Therefore, reducing water present in the vacuum system is of prime concern for most vacuum users.

There are three strategies available for minimizing the amount of water:

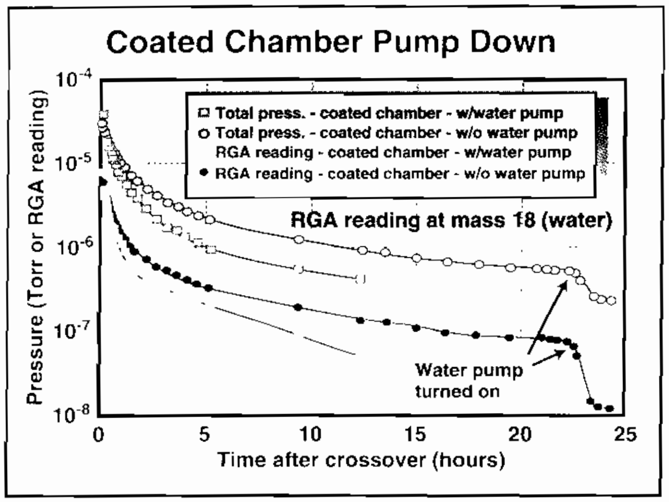
- minimize exposure of the process chamber walls to water
- drive the adsorbed water off quickly (increase outgassing rate)
- pump the water vapor off faster (increase pumping speed).

Minimizing the chamber's water exposure requires, in the ideal, a staged series of chambers of ever-increasing vacuum levels, as in cluster tools. Another approach is to use a dry gas purge of the system when venting to ambient. Increased outgassing requires the application of sufficient energy to detach the molecules from the walls, as in baking or the use of plasma precleans. Increased speed results from the addition of more or better water vapor pumps, or from improved chamber layout designs to improve gas availability to the pumps.

We adopted the strategy of increasing water vapor pumping speed by the addition of a single stage, closed loop, helium refrigerated On-Board Waterpump installed on an existing small port (Fig. 1). By placing the pump's large cryogenically cooled surface directly in the system and attaching the refrigerator to it through the small port, we added much more water vapor



2. Tests comparing pressure histories with and without the added water pump for a clean system, directly following a system clean and target change.



3. Pumpdown of a coated vacuum system without the added water pump takes about 23 hrs, but only 9.5 hrs with the pump.

pumping surface than was available with the port alone and minimized conductance losses between the chamber and the pump. Since a cryogenic surface is the most effective means to pump water vapor, this design strategy maximized effective water vapor pumping speed.

Process

The system that we modified was a Varian 3190 sputterer that deposits films in a continuous serial mode. The particular system tested here was chosen because it deposits aluminum and titanium for all single and double layer processes, thus being indicative of the most commonly used sputter configurations. One or two cassettes of wafers are placed on a load station; the wafers are fed sequentially through the process chamber by means of a transfer plate. The transfer plate rotates clockwise and steps the wafer through four process stations.

The first station is an rf etch, the second is titanium deposition and the third and fourth are aluminum deposition stations. Any combination of stations can process wafers independent of the other stations. After the wafers have stepped through all four process stations, they return to the wafer cassette.

In production, the system's baseline operational cycle between target changes proceeds as follows: After the machine reaches a typical base vacuum of 5.0 × 10^{-7} Torr in 18-20 hrs, several batches of wafers are processed to clean and condition the system and check out process parameters. The machine then processes product full time for approximately 10 days until requiring a target change. The change takes roughly 4 hrs, during which time normal maintenance (e.g., cryopump regeneration) occurs.

Performance testing

To observe system performance with and without the added water pump, we used the following test sequence:

- Pump chamber to 2 × 10^{-7} Torr.
- Vent chamber with nitrogen.
- Open process chamber door for 30 min.
- Close chamber, rough pump.
- Initiate timing when hi-vac valve opened.

Pump down to base pressure took 23 hrs without the added water pump, and about five hrs with it.

We tracked total pressure with a Bayard-Alpert ion gauge and selected species' partial pressures with a Leybold Inficon H200M residual gas analyzer (RGA). These were tracked only until the total pressure reached 5 × 10^{-7} Torr. The ambient conditions during all testing were 71-73 F and 39-40% relative humidity.

The first pair of tests, illustrated in Fig. 2, compares pressure histories with and without the added water pump for a clean system, that is, directly following a system clean and target change. The total pressure and water partial pressure track with the same slope. At any time, the total pressure with the added water pump is about one third that without the pump. In this test, pump down to base pressure took 23 (projected) hrs without the added water pump and about 5 hrs with it.

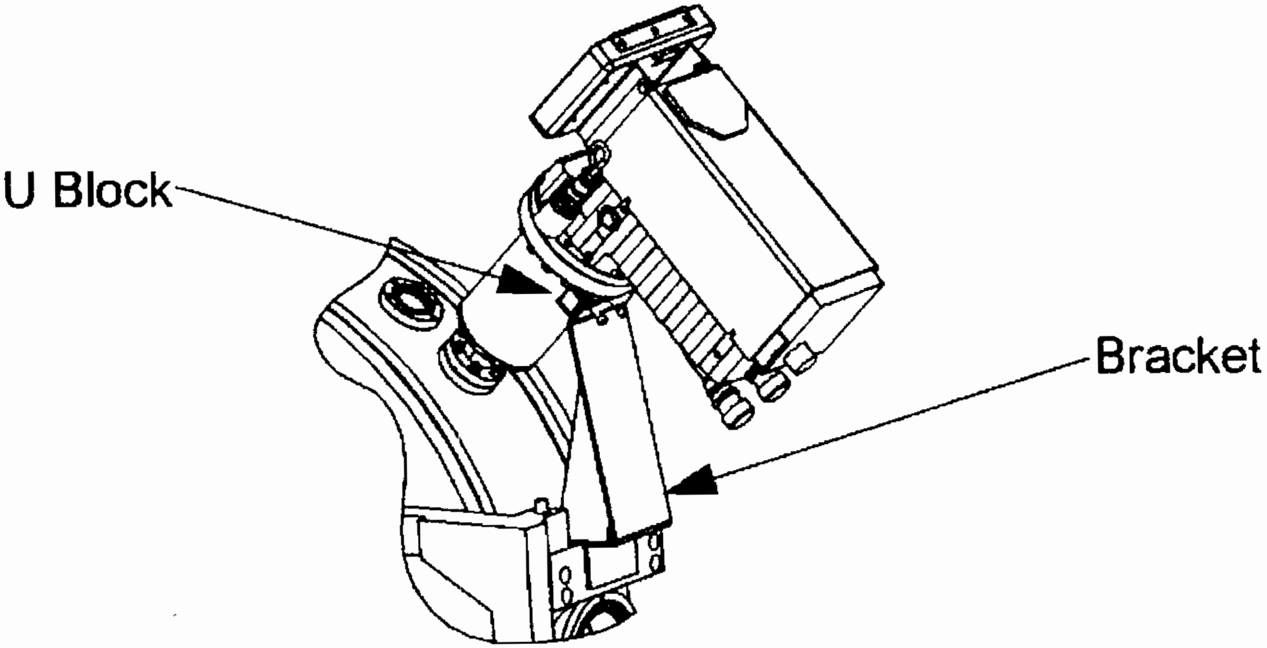
A second set of tests illustrates pump down effects on a coated chamber, i.e., one that has had some system incident between scheduled target changes that necessitates unplanned breaking of the chamber vacuum and exposing it to atmosphere. To simulate this event, we repeated the test protocol after depositing aluminum on 670 wafers and titanium on 250 wafers. As shown in Fig. 3, the pumpdown without the added water pump takes, again, 23 hrs, and with the pump 9.5 hrs. Note also the effect of turning the water pump on at 23 hrs in the upper curve; following a short cool down period, the water partial pressure and the total pressure fall rapidly.

Water was almost always the majority component of the system pressure as measured on the RGA. With the added water pump the partial pressure of water decreased nearly a decade in some cases, so that it became comparable in magnitude to the hydrogen peak at base pressure.

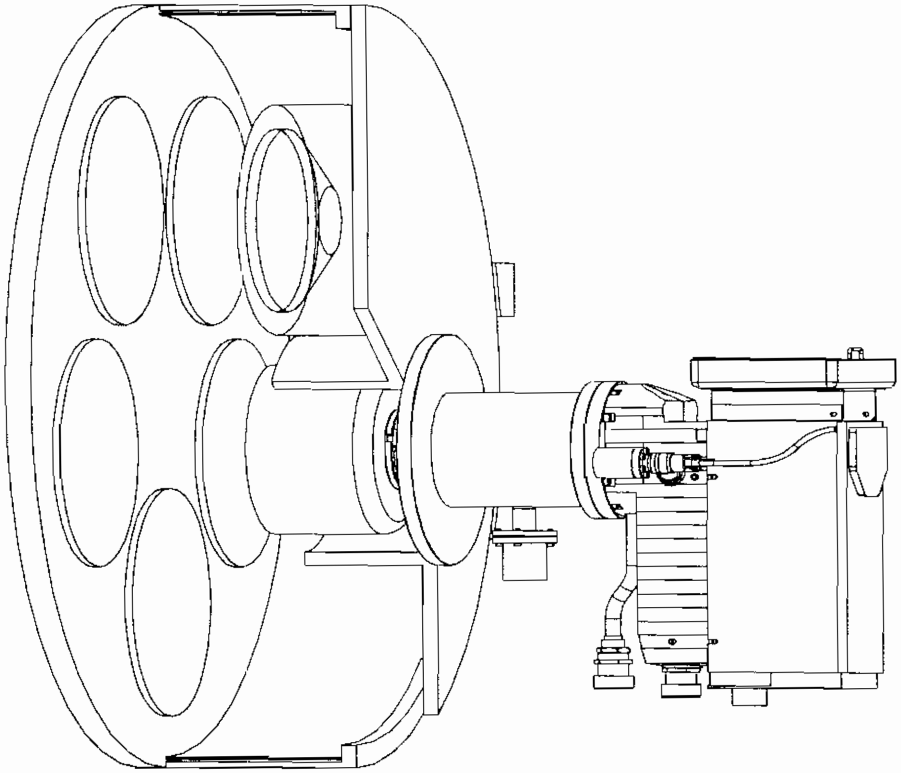
Reflectivity

A key measure of metal film quality is reflectivity. Gaseous or particulate contamination can form discontinuities in the film, scattering incident light and

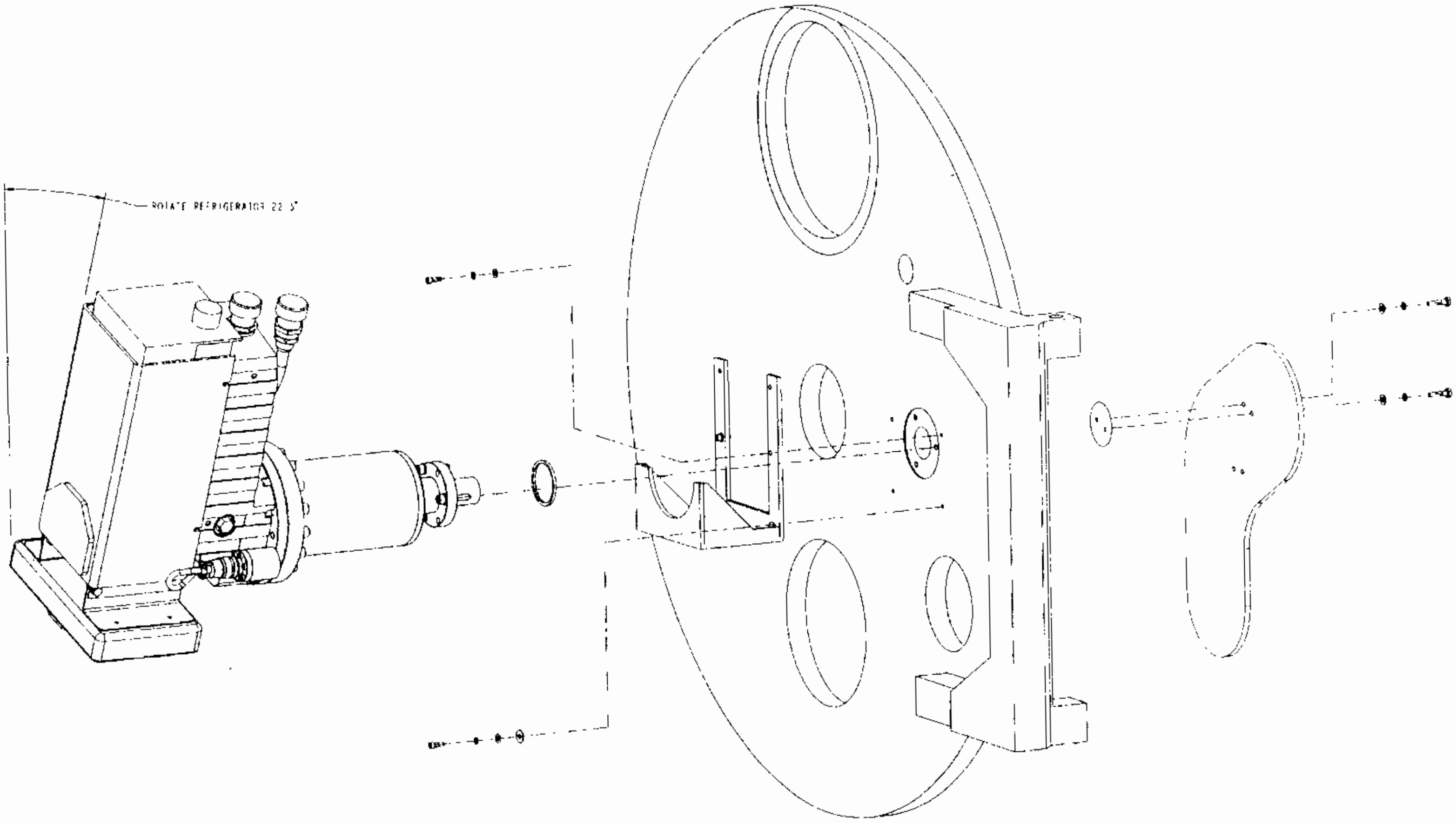
Varian 3190 2 3/4” Top Accessory Port



Varian 3190 Target Mount Waterpump



Varian 3190 2 3/4” Etch Accessory Port



Varian Viewport Mount
On-Board® Waterpump