Characterization Of A Small Form Factor Multipole RGA For Process Chamber Monitoring And For Reduction In Time To Complete Routine Preventive Maintenance

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Abstract. A small form-factor, multipole Residual Gas Analyzer (RGA) has been used to study steady state and post-PM conditions in an Axcelis GSD ion implanter. The RGA properties and specifications are discussed and data is presented to illustrate N2, O2, and H2O pump-down curve characteristics. Baseline performance is compared to performance following invasive activities to determine applicability for eliminating explicit He leak checking requirements and for the determination of how quickly a machine may be returned to production. The target ion implanter was an Axcelis GSD/200E.

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INTRODUCTION

The application of RGA systems to ion implanters is a natural fit. The high vacuum and simple nature of introduced species of an ion implanter is an environment that can be well studied by an RGA. Horiba/STEC manufacture a small form-factor, multipole RGA system which offers variations in performance that is dependent on the chosen sensor head. Intrusion of the sensor head into the vacuum chamber is minimal and less than 5 cm. Protrusion from the vacuum chamber is also much smaller than on conventional RGA systems and is less than 15 cm. The small size allows for novel sensor placement and easy portability between systems or vacuum sub-systems on a given machine. The penalty for the compact size of the head is in time and mass resolution and available mass range. The sensor used in this series of tests (MPA6-5-2/65K) had a maximum time resolution of 0.6 seconds/amu peak, a mass resolution of 0.8 amu and a mass range of 2-65 amu. The system was used primarily in a trend mode to evaluate vacuum response to a number of treatments. The ion implanter used for initial testing of the RGA was an Axcelis GSD 200E, installed in the Portland facility of Innovion Corporation.

INSTRUMENT DESCRIPTION

The Micropole RGA system consists of a sensor head, an electronics module "Spectrum Converter") that attaches to the head and via special cable to a serial interface box for communicating with a Windows-based computer. Finally the vendor supplies WinMPA software to control the sensor and acquire and display the data. Optional hardware for controlling vacuum components via user defined logic in response to sensor output is also available; this hardware was not used for this investigation. The software has a reasonable array of features for defining default and custom data acquisition profiles. The software and system were mostly straightforward to use and only required occasional references to the system manual. The sensor head ships with individualized calibration information which must be entered into the configuration data for the operating software. Since each sensor head is individually calibrated at the factory, no expensive calibration schemes are required by the end user. With a cost in the neighborhood of \$1.5k – \$2.0k, replacing the head on failure or when discernible drift/non-linearity is detected makes for reasonable Cost Of Ownership (COO).

There are a variety of scan modes for operating the sensor: Leak, Scan and Scan & Hold. The software provides for several display formats and in Leak Mode will display a trend for Helium pressure as well as an analog ‘bar’ display similar to what is standard on most dedicated leak checkers. The mode most used in this investigation was a straightforward Scan which scans through the amu range from lowest to highest. There are also a handful of configurable parameters one can use to modify the Scan mode; the most useful of these is ‘Fast Scan’ which ignores intermediate peaks during Gas Trend measurement and so delivers an overall faster data rate. Finally, the Scan & Hold mode completes a single scan and then waits for user direction.

EXPERIMENTAL OUTLINE

The system was tested in He Leak Check mode and in Gas Trend mode using three different trend definition files. In the Gas Trend mode, specific amu peaks were chosen for each of the two trend definition files as being most likely show variation under the specific treatments used. Initially, a trend definition file was configured to detect ion implant species: ^{11}B, ^{19}F, $^{28}N_2$, ^{31}P, ^{40}Ar, along with $^{1}H_2$, ^{4}He and $^{18}H_2O$. A second trend definition file was created to optimize detection of atmospheric leaks into the process chamber and consisted of the following key peaks: $^{1}H_2$, ^{4}He, $^{18}H_2O$, $^{28}N_2$, $^{32}O_2$, ^{40}Ar, and amu 45 (reported[1] to be the most dominant fraction for isopropyl alcohol (IPA)). Finally, for a scan of normal process operation where photoresist outgassing and argon from an active electron shower would be expected, but fast scans were desired, a 4 peak trend definition file was setup using the following amu: $^{1}H_2$, $^{18}H_2O$, $^{28}N_2$, ^{40}Ar.

It should be noted that the data presented here has not been corrected for ionization efficiency. The RGA sensor calibration uses nitrogen (N2) as a standard. This investigation was primarily interested in qualitative results versus absolute pressure measurement.

Gas Trend Mode: Ion Beam Setups

Several different ion beam set-ups were completed to investigate whether the RGA would detect the individual specie components. A uniform set of ion source parameters was selected for all setups to minimize differences between gas species: Gas Flow = 3 sccm, Arc Current was 1 A, Source Magnet was 7 Amps, Arc Voltage was 60 Volts (except for BF_3, where Arc V was 90) and Extraction Voltage was 80 kV.

Ion beams were generated from each of the following source gases: arsine, phosphine, BF_3 and argon. Even though the particular RGA sensor selected for test is unable to detect amu 75, a 75As+ ion beam was set up to see whether any detectable species would be evident as one might expect if high current ion beams caused ‘evaporation’ of previously implanted and/or deposited contaminants. The actual sequence of beam tuning was: $^{75}As^+$ (15 mA), $^{1}H_2^+$(0.7 mA), $^{1}H^+$(0.6 mA), $^{31}P^+$(7.4 mA), $^{1}H_2^+$(0.5 mA), $^{1}H^+$(0.4 mA), $^{11}B^+$(1.6 mA), $^{49}BF_2^+$(3.2 mA), $^{19}F^+$(1.3 mA), $^{40}Ar^+$(4.3 mA). Perhaps due to the sensor head placement (lower portion of process chamber, behind the process disk, but near to the disk Faraday), no ion beam components were detected. Neither were there elevated levels of any of the other scanned peaks, except during use of phosphine gas: the H2 level was elevated and averaged 4E-7 Torr versus 1E-7 Torr for other gas sources.

In a less controlled trial with the sensor head placed very near to the ion beam, expected species were difficult to detect. Most ion beam related species will be driven into machine surfaces with little back-scattering or surface sputtering and so will be unavailable for detection in the background gas of the implanter. It may also be that the ion beam is somewhat contained by the design of the machine.

Gas Trend Mode: Pumpdown Curves

For this phase of the investigation, no ion beams were present in the system, but a variety of activities were carried out to understand how the state of the vacuum chamber changed and to more fully test the capabilities of the RGA system. For this segment, baseline data were recorded along with data for vent recovery, vent recovery with IPA or H_2O cleaning and response to leak introduction. Note: although trends for several amu peaks were recorded, only those showing clear changes are being included in this report.

The first task was to look at baseline levels and understand how a simple vent would affect the vacuum system. Figure 1 illustrates a very fast recovery to baseline vacuum levels after an N2 vent to atmosphere, but with the process chamber door (or ‘clamshell’) held closed. In the absence of exposure to atmospheric water, the vacuum system recovery is excellent.

Figure 2 illustrates how vacuum recovery is affected by full exposure of the vacuum system to room air for a 5 minute period. As expected, there is a marked increase in the time taken for the system to return to baseline levels, especially for the water peak.

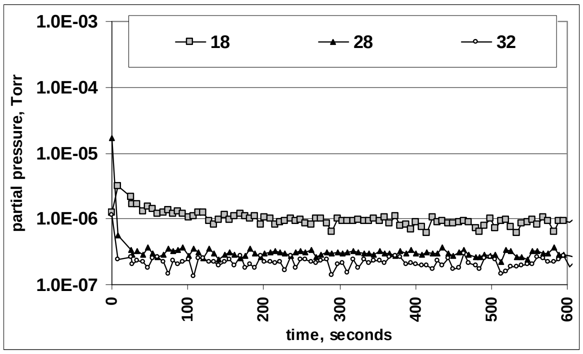

FIGURE 1. Recovery of vacuum state after N_2 vent; chamber door remained closed.

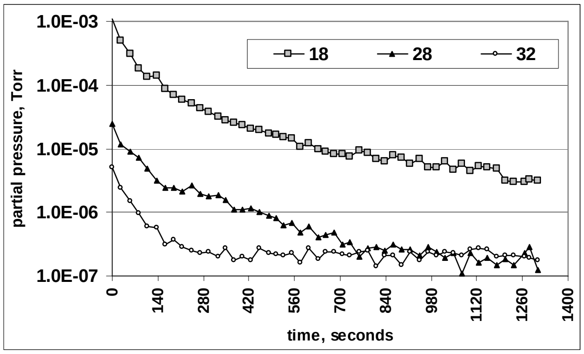

FIGURE 2. Recovery of vacuum state after N_2 vent; chamber door open to room air for 5 minutes.

Next a leak was introduced at the o-ring sealing surface of one of the ports on the vacuum system via inclusion of a foreign object with an approximate diameter of 50 microns. The data appear in Figure 3 which shows N_2 and O_2 reaching an equilibrium state after around 10 minutes while the H_2O peak continues to decline with time.

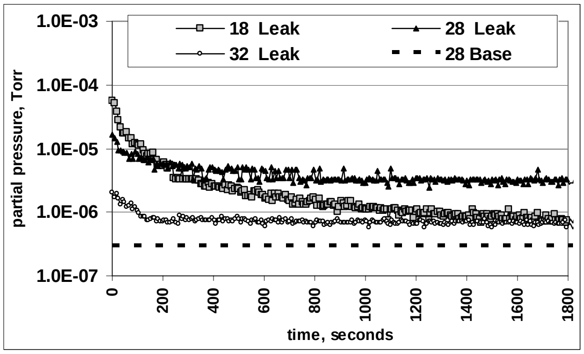

FIGURE 3. Response of system to introduced leak; atmospheric components remain well above baseline.

Finally, a variety of other test cases were investigated: wipe chamber with $H_2$0, wipe chamber with IPA, wipe chamber with H_2O and IPA, et cetera. In these several trials, very little new was discovered except that IPA, or its most common vacuum fraction amu 45, cleared the system very rapidly.

Gas Trend Mode: Wafers In Process

For this phase of the investigation, the RGA system was running with a 4 peak trend definition file and with Fast Scan enabled. Two types of wafer process were captured: 1)high current, single pass process with electron shower and 2)medium current, quad angle process without electron shower. Figure 4 illustrates the load/unload and implant sequence for 2 batches (1 lot) for the first case and Figure 5 illustrates the same total sequence for the second case.

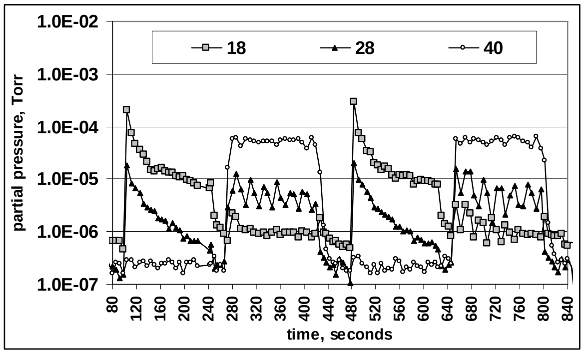

FIGURE 4. Two normal high current process cycles: load/unload and implant with photoresist and argon present. Two cycles.

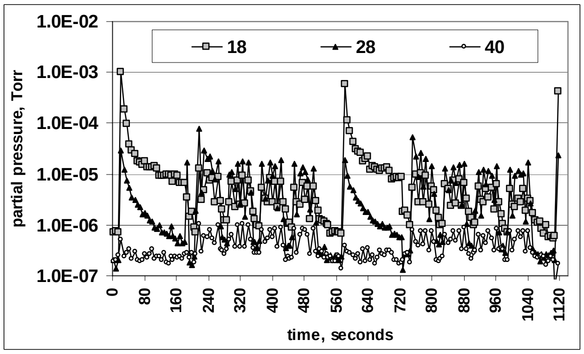

FIGURE 5. Two normal medium current, quad angle process cycles: load/unload and implant with photoresist present, but no argon.

The RGA captured the most relevant information for these processes. In the high current case, the argon is seen to switch on at the beginning of scanning which then coincides with increased detection of amu 28 (N_2, CO). It is interesting that the detected level of amu 18 (H_2O) is seen to decrease during scanning. It is not clear whether this is due to rapid outgassing induced by the ion beam or whether the RGA sensor was being somewhat overloaded by the elevated pressures. This feature bears additional investigation in future.

The quad angle implants are clearly seen in the four groupings of elevated N_2 levels and a modulation of the amu 18 levels. In these processes, without a high argon background, the amu 18 levels are more consistent with a simply decay over time (despite the obvious moudulation in level).

Helium Leak Check Mode

The Helium Leak check mode was tested only briefly for functionality. In this mode the system is configured to analyze only amu 4 and the software provides for two primary data displays: 1)trend display of helium pressure on log scale and 2)'analog' bar graph for rapid response. After creating a known leak at a particular fitting, helium was introduced to the general area and was immediately seen on the displays. The software also provides an audio output, but as it was running on a laptop computer, speaker volume was inadequate to overcome the background noise in the Fab. For this application, an external, amplified speaker set-up would be required. Overall function in He Leak Check mode was reasonable and the small size of the sensor makes it easy to move between various parts of an ion implanter. The system could reasonably be adapted to replace an external He Leak Check tool and its associated COO.

Vacuum Troubleshooting

Use of the RGA system to troubleshoot difficult to resolve issues related to process delivery is expected to be its most valuable application. For example, after a baseline for a particular machine is known, it would be simple to run an RGA scan during a process shutdown event and look for particular contaminant signatures. In any given year, there will be 1 event for every implanter or two that is not resolved by a standard He leak check or other common corrective maintenance approaches. The compact size of this multipole RGA would be a great asset in facilitating this type of problem solving. During the time under study, no such event was available to pursue and report on.

Another area of promising application is evaluation of high vacuum pump health. Both turbo and cryo pumps can fail slowly; this type of RGA system could enable simple, periodic checks to alert one to a pump whose performance is degrading.

CONCLUSION

The compact multipole RGA system was tested on an Axcelis GSD implanter and performed as expected for all phases of this investigation. It was helpful to have a visualization of the vacuum behavior of target species and their response to a variety of treatments.

This system has great potential for aiding in troubleshooting situations that do not yield good answers to conventional approaches and techniques. Further, the cost and COO of the system are such that it would be economical to permanently mount an individual sensor on each machine. The software allows for each sensor in a facility to have its own configuration file so the electronics can easily be moved from one system to another.

REFERENCES

1. INFICON Spectra Library Card, copyright 2002.