

# Effect of Cleaning Parameters on Cleaning Effectiveness in an SEM Equipped with an Evactron® RF Plasma Anti-Contamination Device

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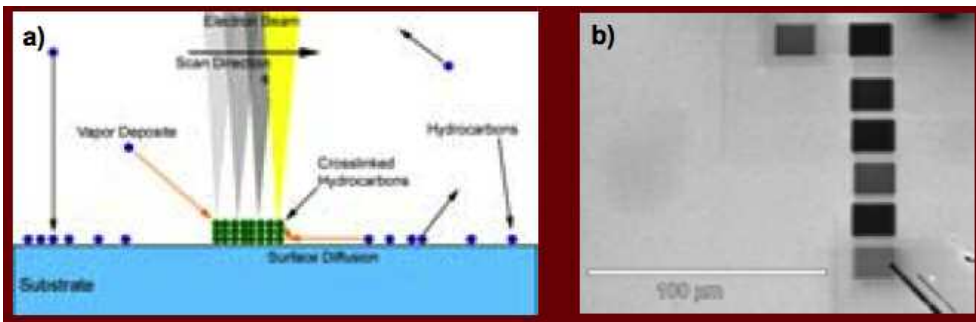
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## Introduction

- It has been demonstrated previously that plasma cleaning an SEM chamber with the Evactron® RF plasma system greatly decreases the amount of carbon contamination built up on a sample surface.
- There are several parameters that can be adjusted to maximize the cleaning effectiveness:

1. Cleaning Pressure
2. Plasma Power Setting
3. Gas introduction

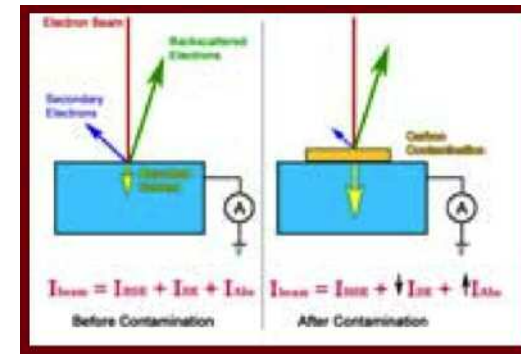
- In this study we have determined the effect on varying the chamber pressure while cleaning with a power setting of 10.0 and introduction of air.



**Figure 1a)** Diagram showing the electron beam inducing carbon contamination on the surface of an SEM samples as it rasters across it. **b)** SEM image of deposited contamination on an In P substrate obtained at 5kV, 2.0nA beam current, over a 16.5 m X 13.2 m area after 1000 sec of raster time.

## Background

- Typical SEM examination results in the deposition of cross-linked hydrocarbons on the surface of the sample (fig 1a) which is evident by the darkened areas left after rastering the beam (fig 1b).
- Sources of these hydrocarbons include
  - 1) Backstreaming of roughing pump
  - 2) Sample borne surface contamination
  - 3) Background hydrocarbons of the SEM vacuum environment.
- The Evactron® uses a low-powered RF plasma to create oxygen radicals from air or supplied oxygen which then oxidize hydrocarbons and form gaseous species from the SEM chamber and/or specimen.
- The process results in formation of C0, H<sub>2</sub>O and CO<sub>2</sub> which can then be removed by the vacuum.
- The cleaning effectiveness is monitored by the change in the specimen current as determined previously using current amplifier and a data logger.



**Figure 2** Diagram showing the relationship between electron beam BSE, SE and specimen current signals before and after contamination.

# Experiment Optimizing Cleaning Pressure

1. InP is used as the substrate and is cleaned in a barrel type plasmaasher for 5 minutes prior to placement in the SEM.
2. Sample is placed on an SEM mount with a Faraday cup attached Figure 3a.
3. Exposure conditions for contamination deposition are:
  - 5 KeV beam voltage
  - 2.0 nA beam current
  - Beam rastered at 10,000X magnification over a 6.5m X 13.2m area
  - Exposure time is 1000 sec
4. Several contamination depositions were made prior to cleaning to determine state of cleanliness Figure 4a.

5. Operational parameters for Evactron were:
  - Evactronpower 10 W
  - Cleaning gas is room air
  - Cleaning time 20 min
  - Chamber pressure varied (performed at 400, 600 and 700 mtorr) Fig 3c
  - Sample left in chamber while cleaning performed.
6. After cleaning contamination was deposited and the change in specimen current was recorded for each deposition.
7. Several depositions at each condition were performed.
8. Beam current was continually monitored for drift.

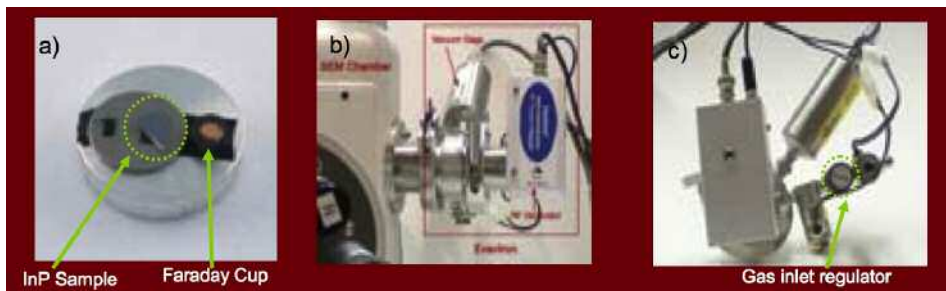


Figure 3a) Image of sample setup. b) Evactron® RF plasma cleaning system attached to a S3200 Hitachi SEM. c) Close up of the Evactron® unit showing gas regulator.

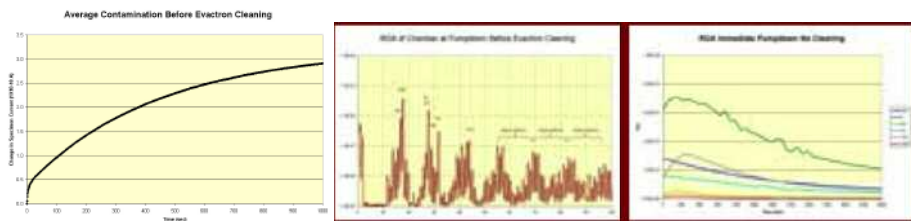


Figure 4a) Graph of change in specimen current as hydrocarbons are deposited on the surface of InP sample before cleaning. b) Mass Spectrum showing a large amount of hydrocarbons present in chamber prior to cleaning. c) RGA trend showing common species present in chamber after pumping down prior to cleaning.

# Results

- Figure 4a shows the typical change in specimen current prior to cleaning of the chamber. This is an average of several depositions made at the start of each experiment to establish the contamination state of the microscope. Figure 4b is the corresponding RGA reading of the Chamber after it has been pumped down prior to cleaning the chamber.
- Figures 5a-c shows the specimen current after cleaning the chamber at 400, 600 and 700 mtorr with air after a certain amount of time since the initial Evactron cleaning (0, 60 min and 120 min) respectively. This shows the recovery time of the hydrocarbon contamination rate. The data is an average of 3 separate experiments performed at that particular atmospheric pressure level. The corresponding RGA (Figures 5d-f) is shown taken at the start of the cleaning process. A dashed line is placed around the  $1 \times 10^{-7}$  level to clearly illustrate the differences between the graphs.

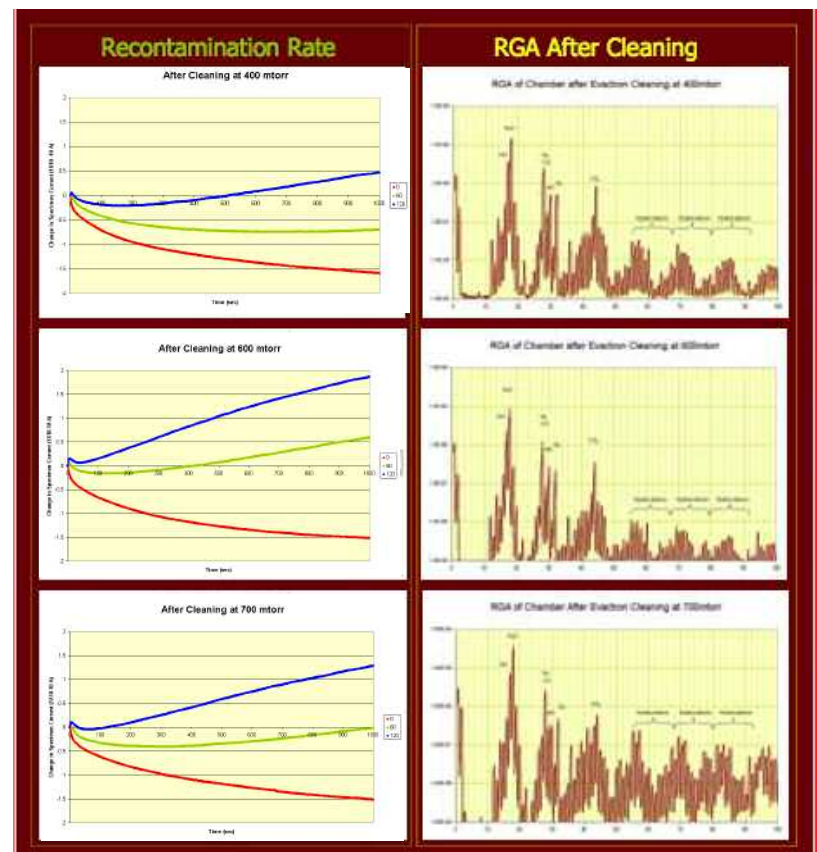
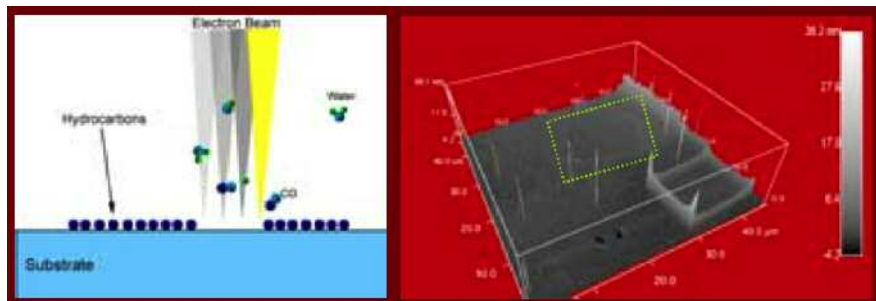


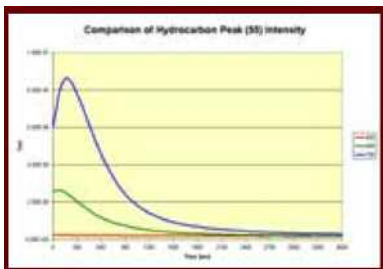
Figure 5a-c) Graphs showing the change in specimen current as hydrocarbons are deposited on the surface of InP sample after Evactron cleaning at atmospheres of 400, 600 and 700m torr respectively. d-f) Mass Spectrum of chamber atmosphere immediately after cleaning chamber at each atmosphere.

# Results

- The data clearly shows that optimum cleaning is obtained when the Evactron is operated at 400 mtorr with air as the supply gas at a power of 10W. The recontamination rate is 1/3 of that run at the other two conditions. There seemed to be little difference between the recontamination rate at 600 mtorr and the one at 700 mtorr.



- The initial cleaning is the same in either condition. The change in specimen current data is essentially the same at time 0 after cleaning at all pressures. This initial cleaning indicates that specimen surface is relatively free of hydrocarbons. Any hydrocarbons that are on the surface are removed by Electron Beam Chemical interactions between the gasses present in the chamber and any adsorbed hydrocarbons (shown as a negative value in the slope of the graph). This is clearly supported by AFM data which shows little or no height differences between the outer and inner contamination area (outlined area).



- RGA analysis shows that hydrocarbons are more abundant in the chamber when cleaning is performed at the higher pressures. Figure 6 shows a comparison of the RGA values for each pressure in the hydrocarbon range of the spectra. The overabundance of O present at the higher pressures may actually clean more effectively, but in essence begins to breakdown the lubricants used for the stage. This effectively increases the hydrocarbon content in the chamber atmosphere.

- Since the contamination rate is increasing with time since cleaning and the hydrocarbon content in the chamber decreases with time, it is evident that the primary source of hydrocarbons is surface diffusion limited. The hydrocarbons adsorb onto the substrate surface and then migrate.

# Conclusion

- Under the conditions analyzed (air as supply gas and power of 10W) the optimum operating pressure for chamber cleaning was found to be 400m torr.
- A simple experiment may be necessary for each instrument under each operating condition to determine optimum cleaning efficiency.
- Using a standardized sample such as presented in this experiment is a quick and effective means of obtaining the optimum cleaning conditions.
- Surface diffusion appears to be the predominant phenomenon in the deposition of contamination in this experiment.

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