Tip of the month/No. 21

Analysis of airborne molecular contamination (AMC) conditions inside FOUPs

Question: How to analyze airborne molecular contamination conditions inside FOUPs easily and with confidence?

Answer: With our contamination management solution APA 302, an in-line monitoring tool for advanced chip manufacturing in cleanroom environment, and a good understanding of desorption phenomena.

Background: Gaseous compounds present in the air of a cleanroom, process equipment or a container which can contaminate surfaces or products are called airborne molecular contamination. AMC can create serious damage generating important yield loss and massive performance degradation in leading edge manufacturing plants. Several containment actions can be put in place, but the question is: "How to analyze airborne molecular contamination conditions inside FOUPs easily and with confidence?"

In this tip of the month, we will focus on the FOUP, which is the container that transports and stores wafers in the semiconductor factory, and we will take the example of hydrogen fluoride (HF) gas, as it is one of the most critical sources for airborne molecular contamination today.

Dedicated HF measurement is available with APA 302. After two minutes of sampling through the FOUP filters, it provides the HF concentration with high sensitivity (at part-per-billion range!) thanks to its new analyzer based on cavity ring down spectroscopy. Detailed information is available on our website:
http://www.pfeiffer-vacuum.com/products/contamination-management-solutions/apa /container.action.

So it is easy to obtain the real-time AMC concentration based on APA 302 results, but it is important to understand AMC behaviour within a FOUP environment in order to draw the right conclusions. Indeed, the FOUP is not an inert and static atmosphere where AMC is concerned, and several adsorption or desorption phenomena occur.

It can be broken down into different steps:

- FOUP atmosphere is contaminated due to HF outgassing from the wafer surface HF molecules are adsorbed by the FOUP surface knowing that the HF concentration on the FOUP surface is proportional to the HF concentration inside the FOUP atmosphere according to Henry's law:

  $C_s = S \times C_g$
  S is solubility of HF in polymer
  C_s is HF concentration on polymer surface
  C_g is HF concentration in FOUP atmosphere

- Then, HF diffusion (characterized by Fick's law) will occur inside the FOUP material:

$$\frac{\partial C(x,t)}{\partial t} = D \times \frac{\partial^2 C}{\partial x^2}$$

  D is diffusion coefficient
  C(x,t) is the local gas concentration at a position x inside the material thickness and at time t

It means that the longer contamination remains inside the FOUP volume, the deeper the HF contaminant will diffuse inside the FOUP material. Moreover, as the FOUP acts as a "sponge", it means that the concentration inside the volume will decrease because of this HF adsorption.

- Finally, if the contamination source is removed from the FOUP volume then HF desorption will occur from the FOUP wall to the FOUP atmosphere.

As you can see, diffusion and desorption phenomena are not fixed (they are dependent on time, material and concentration) thus it is not possible to anticipate what the HF variation will be for each situation. As a matter of fact, during a test plan based on APA 302, it is mandatory to carry out measurements at fixed time intervals.

The following steps illustrate the importance of time for contamination comparison:

1) Identification of a dry etching process using fluorinated gases (e.g. CF_4, C_4F_8, SF_6)
2) Selection of a FOUP with 25 wafers and application of this process
3) FOUP storage for two hours
4) APA 302 measurement with HF analyzer
5) Wafer removal and FOUP closing
6) APA 302 measurement immediately after FOUP closing
7) APA 302 measurement two hours after FOUP closing

Please see below an example of the results, obtained with a standard polycarbonate FOUP:

	2 h after dry etching	Just after FOUP closing	2 h after FOUP closing
HF value (ppbv) monitored with APA 302	100	< 0.5	20

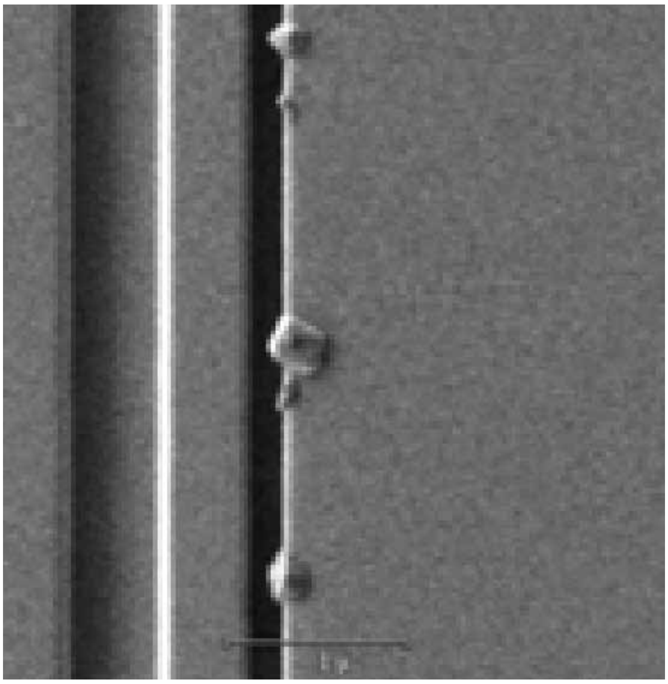
Two hours after dry etching, we observe that the FOUP atmosphere contains a high concentration of HF due to wafer outgassing (100 ppbv). Defect growth may occur on the wafers during queue time with those high values.

Identification of the steps generating these high values (>10 ppbv) with APA302 is key to keeping the yield under control in advanced semiconductor manufacturing.

If wafers are removed from the FOUPs, the concentration measured right after FOUP closing is back to cleanroom concentration (<0.5 ppbv).

The FOUP was indeed opened in clean air conditions, and clean air was introduced into the FOUP. If APA 302 is used just after FOUP closing, desorption did not have enough time to fill the FOUP volume, leading to a bad interpretation of the FOUP cleanliness status.
Indeed, two hours after closing the FOUP, the HF concentration increased drastically due to FOUP desorption.

For the same reason, for attaining a FOUP cleaning qualification, the storage time of contaminated wafers has to be considered, because the longer the wafers stay in the FOUP, the higher the diffusion inside the material, and the more difficult it is to remove contamination with standard deionized water cleaning.



Defect growth occurring during queue time due to high HF contamination

We have described here some generic protocol to efficiently use APA 302 to analyze FOUP conditions.
Should you have any additional questions regarding your test plan with APA 302, please do not hesitate to contact Emmanuelle.Veran@pfeiffer-vacuum.fr .

Do you have a question yourself which you would like us to answer on this page as a new tip of the month? If so, please let us know (info@pfeiffer-vacuum.de)

We would be happy to assist you in optimizing your vacuum solutions for specific applications – go ahead and ask us!
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