# TIPS AND TRICKS FROM THE EXPERTS

## Analysis of airborne molecular contamination (AMC) conditions inside FOUPs

Production processes that are carried out in cleanroom environments set high demands on the vacuum system. Even smallest particles can cause severe process restrictions, performance loss, and thus economic damage. It is therefore important to control and analyze the particular production environment so that the risk of contaminations is kept at a minimum.

### AMC – a danger for cleanroom processes

Gaseous compounds present in the air of a cleanroom, the process equipment or a container which can contaminate surfaces or products are called airborne molecular contamination (AMC). AMC can create serious damage and generate important yield loss as well as 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 Front Opening Unified Pod (FOUPs) easily and with confidence?"

### APA systems for analyzing AMCs

The APA 302 is a unique in-line monitoring system for the measurement of AMCs in a transportation box, the so-called FOUP, and the surrounding environment. The APA 302 is available with a special measuring function for hydrogen fluorides (HF). It determines the concentration of hydrogen fluorides within two minutes after taking a sample through the FOUP filters. This measurement is carried out with high sensitivity in the ppb-range thanks to a Cavity-Ring-Down-Spectroscopy (CRDS) based analytical system.

The AMC concentration can be obtained in real-time based on the APA 302 results.

But it is important to understand the 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:

- The FOUP atmosphere is contaminated due to hydrogen fluoride 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:

$Cs = S \times Cg$
S is solubility of HF in polymer
Cs is HF concentration on polymer surface
Cg 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 the diffusion coefficient
C(x,t) is the local gas concentration at a position x inside the material thickness and at time t

The conclusion of this issue shows that the longer the 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, HF desorption will occur from the FOUP wall to the FOUP atmosphere.

Thus, diffusion and desorption phenomena are not fixed (they are dependent on time, material and concentration). So 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 in the table 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 |

Table 1: Example of results obtained with a standard FOUP

Two hours after dry etching, it can be observed 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 APA 302 is vital to keep 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 the 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. Therefore, the storage time of contaminated wafers has to be considered for attaining a FOUP cleaning qualification. The longer the wafers stay in the FOUP, the higher the diffusion is inside the material and the more difficult it is to remove contamination with standard deionized water cleaning.

The descriptions provided above are some generic protocol how to efficiently use APA 302 to analyze FOUP conditions.

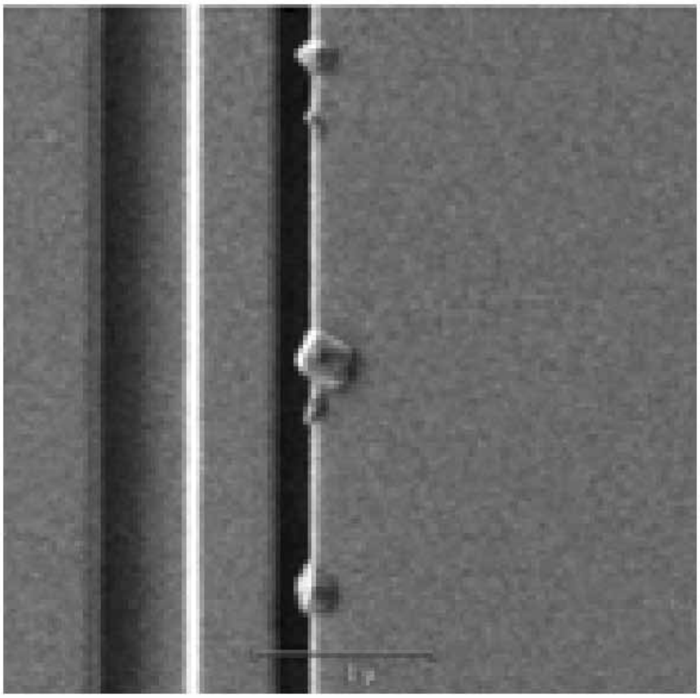

Figure 1: Defect growth occurring during queue time due to high HF contamination

## VACUUM SOLUTIONS FROM A SINGLE SOURCE

**Pfeiffer Vacuum stands for innovative and custom vacuum solutions worldwide, technological perfection, competent advice and reliable service.**

## COMPLETE RANGE OF PRODUCTS

**From a single component to complex systems:**
**We are the only supplier of vacuum technology that provides a complete product portfolio.**

## COMPETENCE IN THEORY AND PRACTICE

**Benefit from our know-how and our portfolio of training opportunities!**
**We support you with your plant layout and provide first-class on-site service worldwide.**

**Are you looking for a perfect vacuum solution? Please contact us:**

**Pfeiffer Vacuum GmbH**
Headquarters · Germany
T +49 6441 802-0
info@pfeiffer-vacuum.de

**www.pfeiffer-vacuum.com**

PFEIFFER VACUUM