APPLICATION NOTE

MINIMIZING FLUORINE-INDUCED DRIFT IN CAPACITANCE MANOMETERS

PROBLEM

Etch processes that employ fluorine or fluorine-bearing gases can experience a transient burn-in effect that produces an initial drift in the output signal from standard capacitance manometer vacuum sensors. This transient is due to non-uniform changes in the surface of the process-facing sensing diaphragm in the manometer. This Application Note discusses the root causes of this transient behavior and presents the unique design characteristics of the pressure sensor in the E28 and DA02 Baratron heated, absolute capacitance manometers that address this issue.

BACKGROUND

Capacitance Manometers

Figure 1 shows the main components of a modern capacitance manometer. The pressure sensing element is a thin diaphragm that is exposed to the pressure or vacuum being measured via the inlet tube. An electrode structure, typically a ceramic disk with conductive pathways, is mounted in the reference cavity behind the diaphragm. Pressure differences between the process and the reference cavity deflect the diaphragm slightly, changing the distance between it and the electrodes. Variations in this distance produce variations in the capacitance between the diaphragm and the electrodes, and the variation in electrical signal is proportional to the pressure change.

The signal is amplified by the on-board electronics and output to the device's electrical connector for transmission to pressure indicators and process controllers.

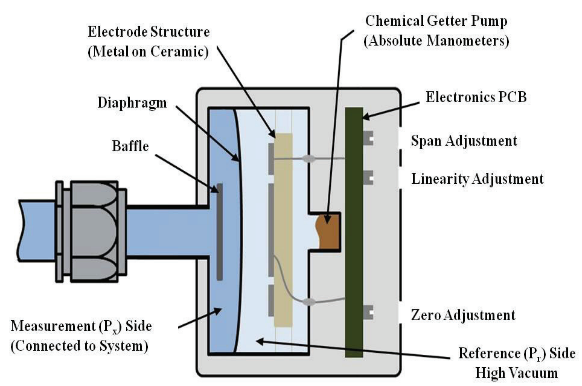

Figure 1 - Capacitance manometer schematic showing the internal components and functional zones

Drift in Capacitance Manometers

Early capacitance manometers used in some deposition and etch processes suffered from drift in the pressure signal. Investigations revealed that the source of this drift was the deposition of solid material on the sensing diaphragm. The origin of this material was found to be byproducts from the process. Some processes directly generated condensable gases that deposit solids on the "wetted" surfaces within the manometer. Other processes used corrosive gases such as fluorine and chlorine that were found to react with internal components of some manometers, causing corrosion and/or physical damage to the diaphragm and other manometer components.

Deposited material on the diaphragm changes its mechanical characteristics. This changes the relationship between pressure, diaphragm deflection, and capacitance signal as the thickness of the deposit increases. This phenomenon then shows up as drift in the manometer's pressure reading.

Heating the sensing cavity of a capacitance manometer to a constant, high temperature (e. g., 100°C) minimizes the deposition of solids on the sensing diaphragm by maintaining any condensable gases from the process in the vapor phase. If this is coupled with the use of corrosion-resistant materials within the manometer sensing cavity, sensor drift due to deposited solids can be minimized. Additionally, maintaining capacitance manometers at a constant temperature yields inherent improvements in the repeatability and accuracy of the pressure measurement.

Heated capacitance manometers such as the E28 and DA02 Baratron capacitance manometers from MKS Instruments (Figure 2) have found applications in etch processes requiring robust, accurate pressure measurements, all occurring in an environment that contains corrosive and condensable gases. In these manometers all internal, wetted surfaces in the sensor are fabricated from Inconel® and Incoloy® nickel alloys, which provide the best available corrosion resistance. These sensors can be heated to 100°C and offer accuracy better than ±0.25% of reading and control that ensures both stability and repeatability of the sensor output. The internal structure of the sensor is designed to nearly eliminate the deposition of any process byproducts on the sensing diaphragm in the gauge, minimizing signal drift from this source.

Figure 2 - MKS Instruments DA02 Baratron® Capacitance Manometer

While the problem of manometer signal drift caused by deposited materials has been significantly reduced and, in some cases, eliminated in sensors such as the E28 and DA02 Baratron capacitance manometers, it has been found that these manometers can experience a very small level of transient drift on initial exposure to etch processes using fluorine or fluorine bearing gases. This transient effect produces a positive output shift in the range of 0.5 to 1.5 mTorr over several RF hours of exposure. This drift behavior is followed by recovery and subsequent stable operation. Although the transient behavior is small and, up to now, largely ignored, modern semiconductor processes are becoming more and more intolerant of even minor process variation. Thus a solution was required to eliminate the transient behavior.

SOLUTION

The Mechanism of Burn-In Drift

The Inconel sensing diaphragms from the E28 and DA02 sensors that had exhibited burn-in drift were subjected to analysis. As manometer functional assessment for the affected Baratron capacitance manometers found no long-term intrinsic drift, the exhibited drift was directly attributable to the presence of the fluorine process gas.

The analysis indicated that fluorine could induce small changes in the mechanical properties of the sensing diaphragm. If these changes in film properties are non-uniform across the diaphragm surface, then small movements in the diaphragm could occur which are observed as drift. Eventually, fluorine uniformly saturates the entire diaphragm surface, eliminating the transient effect.

Eliminating Burn-In Drift

MKS Instruments employed a multi-physics computerized finite element analyses (FEA) modeling procedure to aid in the re-design of the sensor etch baffle in the Baratron capacitance manometers. This model predicted the effect on transducer output of changes in fluorine behavior across the diaphragm surface, along with a number of other factors. The diagrams in Figures 3 and 4 help in understanding how the MKS sensor used in the 600 series, E28, and DA02 Baratron capacitance manometers has evolved.

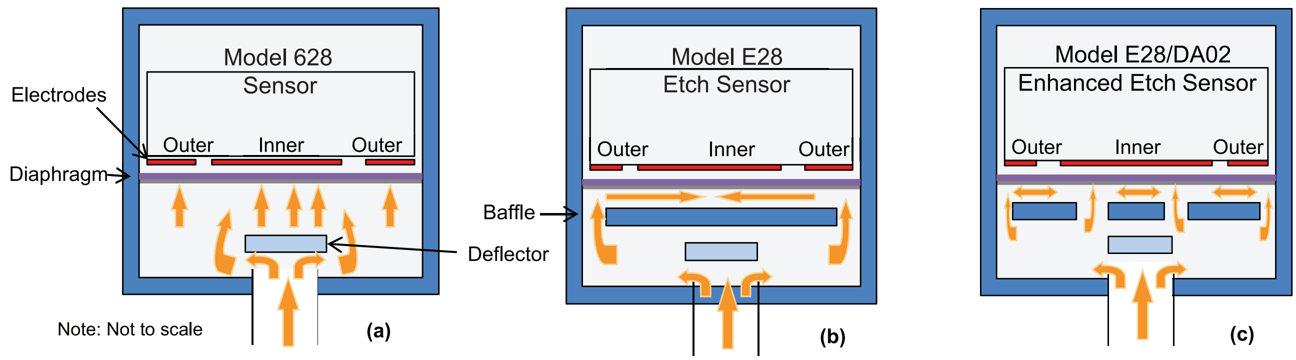

Figure 3 - Manometer baffle evolution

Figure 3(a) shows the original 628 Baratron sensor without any form of internal baffle. The FEA simulation for the 628 sensor clearly shows that fluorine gas flow impinges predominantly on the center of the sensor diaphragm, resulting in fluorine absorption starting at the center of the diaphragm. The validation curve in Figure 4 (the curve labeled "No etch baffle") shows that the non-uniformity of exposure to fluorine-containing process gas in this case produces a negative transient. The transient persists until the fluorine has saturated the surface over the entire diameter of the diaphragm.

Figure 3(b) illustrates the etch baffle configuration used in the current version of the E28 and DA02 Etch sensors. This monolithic baffle occludes the entire central section of the diaphragm from the incoming fluorine gas stream, directing the gas to the periphery of the diaphragm. This design produces a reversal of the negative signal observed for the unbaffled sensor ("Standard etch baffle" in Figure 4). Figure 3(c) shows the design employed in the new Enhanced Etch Sensor. This design was developed using FEA simulations of the fluorine gas flow patterns. It directs the incoming fluorine gas to intermediate positions on the diaphragm.

This results in more balanced and uniform absorption of fluorine across the diaphragm with a concomitant reduction in the transient effect (Figure 4). Note in Figure 4 that in all cases, the transients in the signal dissipate following the initial fluorine exposure, indicative of saturation of the surface by fluorine.

FEA simulations of the flow patterns of fluorine gas within the Baratron capacitance manometers have thereby enabled the design of a simple geometric insert in the sensing cavity of the sensor that produces a significant improvement in sensor performance. The re-designed etch baffle improves the uniformity of fluorine absorption across the surface of the sensor diaphragm successfully reducing the magnitude of the burn-in transient from 1.5 mTorr down to less than ±0.3 mTorr, an 80% reduction in the signal.

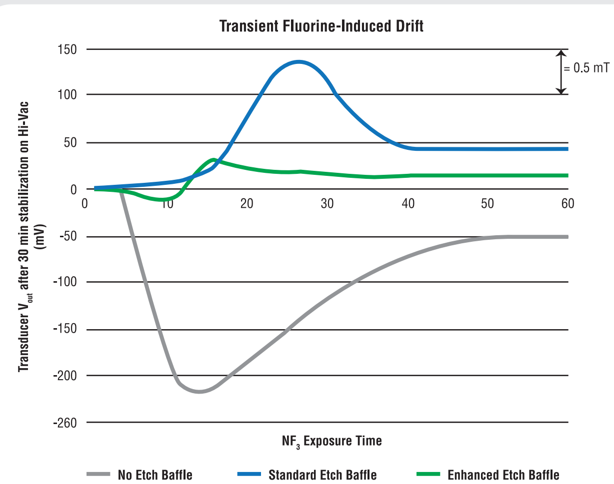

Figure 4 - Validation data for the effect of fluorine absorption on capacitance manometer drift and for the impact of different etch baffle designs

CONCLUSION

Etch processes that employ fluorine or fluorine-bearing gases can experience a transient burn-in effect that produces an initial drift in the output signal from standard capacitance manometer vacuum sensors. This transient is due to non-uniform changes in the surface of the process-facing sensing diaphragm in the manometer. It persists from the initial exposure up to several RF hours of etch operations. FEA modeling was used to develop an alternative baffle that achieves significant improvements in the uniformity of exposure to fluorine-containing process gases across the entire surface of the sensing diaphragm. This uniformity of gas exposure maintains uniform mechanical characteristics in the diaphragm surface which, in turn, significantly reduces the signal/change upon initial fluorine exposure. A reduction in burn-in drift of 5x was demonstrated at both MKS testing facilities and customer sites. Although the results here are specific to fluorine, it is expected that the improvement will be seen in manometer response to other halide gases.