

Preventing Contamination in Dielectric Plasma Etch Processes by Installing Point of Use (POU) Pall Purifiers

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Dielectric etch occurs in dry etch tools, typically Inductively Coupled Plasma (ICP) or Transformer Coupled Plasma (TCP) type chambers. These types of plasma chambers operate at low pressures; and high-density plasmas are created by two independently driven radio frequency sources.

The process sequences prior to the dielectric etch step include oxide deposition followed by photolithography steps. The dielectric etch is an anisotropic etch process that removes the dielectric (silicon oxide, silicon nitride) and the overlying photoresist mask.

The dielectric etch recipe must provide the critical dimension and profile control needed to etch the high aspect ratio features that are required in dense memory chips. The process also must be capable of delivering the high selectivity required to preserve the ultrathin 193 nm photoresist and the underlying nitride etch stop layer used for 90 nm and 65 nm geometries in the industry's fastest logic chips.

Carbon monoxide (CO) is used today in many dielectric etch recipes because CO provides higher selectivity and greater profile control than fluorocarbon and oxygen-based etch processes. The addition of CO to the etch recipe prevents loss of anisotropy by forming sidewall passivating films as illustrated in Figure 1(d)¹. With fluorocarbon-based recipes, the etch profiles are more isotropic in nature, as illustrated in Figure 1(a)¹ and Figure 1(b)¹.

Dielectric Etch Chemical Framework

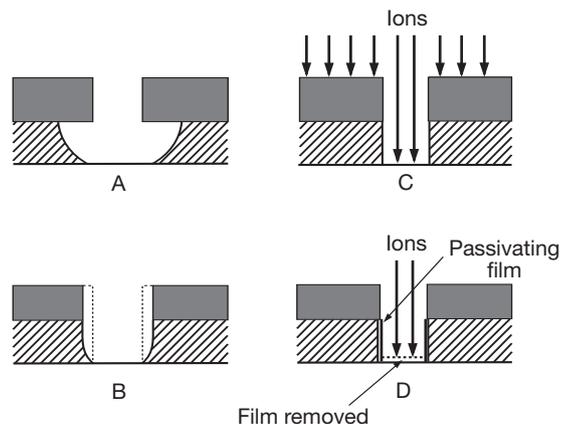
Dielectric etch plasmas are complex due to dissociated reactive species of feedstock gases. Etch process requirements on etch rate, selectivity, anisotropy, and uniformity dictate the feedstock gases.

Feedstock gases are disintegrated in the plasma to form free radicals (etchants) that react with the surface layer and produce volatile gaseous by-products, which detach and get pumped out of the plasma tool.

The ratio of reactive to non-reactive flux at the surface layer is an important process parameter; a high ratio can lead to isotropic etching and a low ratio can lead to thin film deposition. Oxygen can be added to increase the reactive percentage by converting non-reactive species to reactive. For example: $CF_3^+ + O^- \rightarrow COF_2 + F^-$

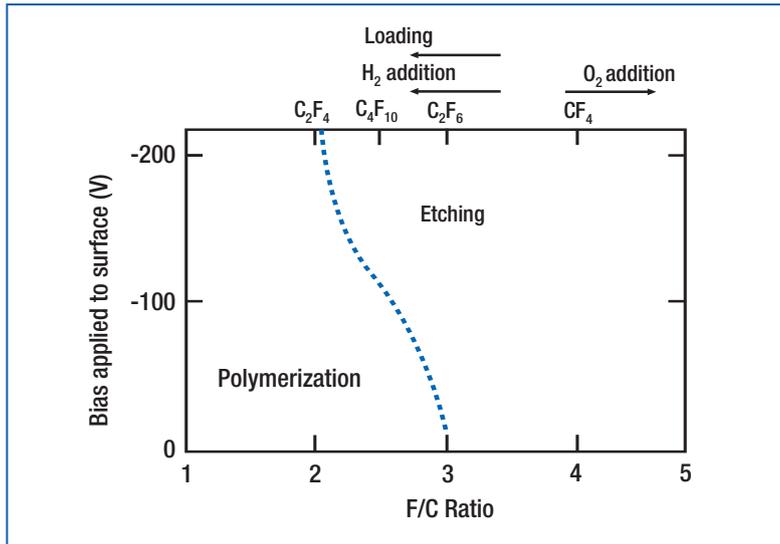
Carbon monoxide provides higher selectivity by acting as a reductant species that binds free F^- reactive species. F^- etching has no selectivity for SiO_2 over silicon. The F^- density is suppressed, while the highly selective CF_x^+

Figure 1.



Plasma etching in integrated circuit manufacture: (a) example of isotropic etch; (b) sidewall etching of the resist mask leads to a loss of anisotropy in film etch; (c) illustrating the role of bombarding ions in anisotropic etch; (d) illustrating the role of sidewall passivating films in anisotropic etch.

Figure 2.



The influence of fluorine-to-carbon (F/C) ratio and electrode bias voltage on etching and polymerization processes in a fluorocarbon discharge.

radical reactive species density is increased. CO decreases the fluorine-to-carbon (F/C) ratio; this enables higher formations of protective polymer layers at the SiO₂/underlayer interface. (Refer to Figure 2.)¹

Thus, controlled addition of oxygen can lead to increased etch rates by increasing more free radicals and volatile etch products; controlled addition of carbon monoxide and hydrogen-containing saturates can lead to decreased etch rates by decreasing free radicals. The user can tailor etch profiles by

controlling the oxidant and reductant species within the plasma.

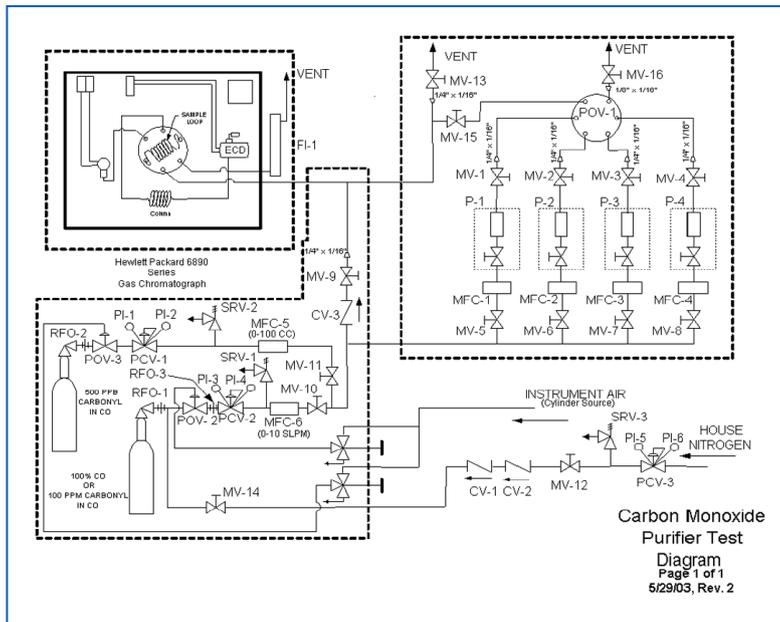
Contaminants in Dielectric Etch Processes

Semiconductor grade (99.997%) CO may contain upwards of 500 parts per billion (ppb) of Fe(CO)₅, 1 part per million (ppm) of Ni(CO)₄ volatile metal carbonyl contamination, and 1 ppm of moisture contamination. In addition, pure CO can react with the nickel and iron found in gas delivery systems, resulting in metal carbonyl formation; higher pressure and moisture concentrations accelerate the formation of metal carbonyls.² Volatile metals and moisture cannot be removed by particulate filtration.

The CO process gas will carry these volatile metal carbonyls and moisture into the dielectric etch process chamber, resulting in deposition of the metals on the wafer. Metallic contamination on wafers detrimentally alters the electrical characteristics of IC devices and potentially could be the source of electrical shorts. Control of metallic contamination is also important to prevent surface resistivity changes, charge breakthrough, and minority carrier lifetime. The deposited moisture can cause corrosion of underlying metal layers.³ Moisture contamination can lead to uncontrolled oxidation of wafer surface metal layers.

In addition, metal carbonyls also could be deposited on dielectric etch chamber surfaces. The subsequent release of toxic metal carbonyls into the atmosphere during preventative maintenance could pose a safety hazard to the personnel conducting the maintenance. The TWA levels are: 50 ppb for Ni(CO)₄ and 100 ppb for Fe(CO)₅.

Figure 3. Test Schematic Diagram

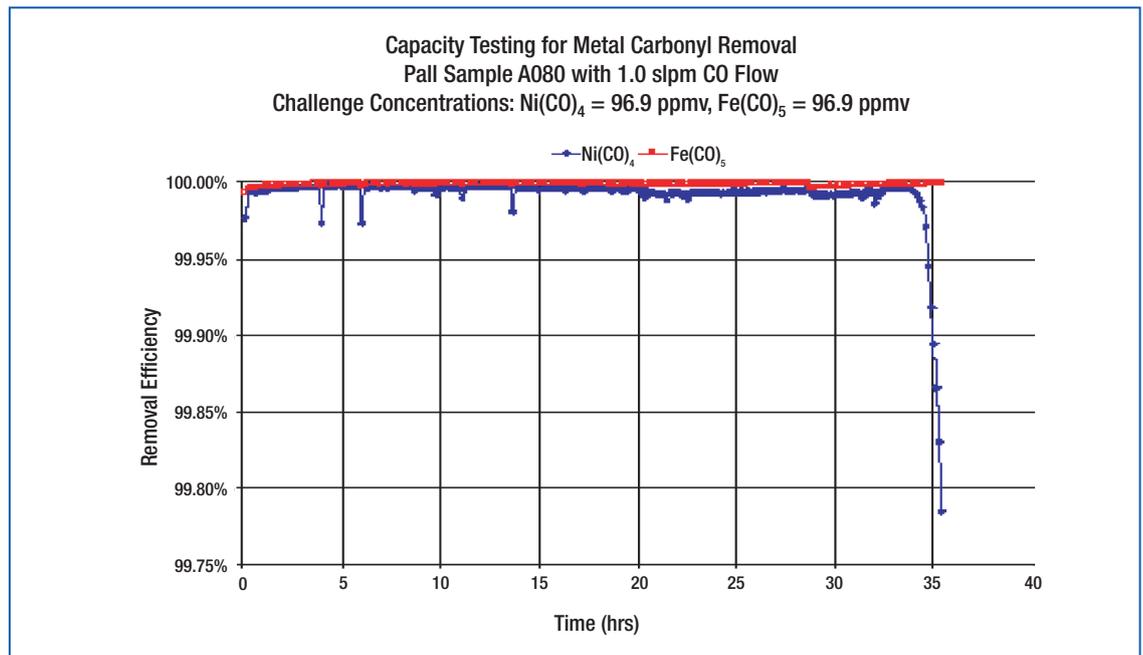


A CO gas purification medium's metal carbonyl removal efficiency and capacity are critical. However, it is equally important that the medium not release metal carbonyls during change out at the end of a purifier's life. This is important because the release of extremely toxic metal carbonyls into the atmosphere during change out would pose an environmental safety hazard to the person conducting the change out. Pall Gaskleen SIP purifiers remove contaminants by irreversible mechanisms, thus negating desorption of contaminants.

Point of Use (POU) Pall Purifiers for Dielectric Etch Processes

POU purification refers to the purifier assembly being placed as close to the plasma chamber

Figure 4.



Pall Gaskleen® 1½" C-seal Top Mount CO Purifier (part number GTMP3SIPCC4) removal efficiency of 96.9 ppm each of Fe(CO)₅ and Ni(CO)₄.

as possible, typically just upstream of the process feedstock gas mass flow controller. The purifier assembly is installed in the ultra-high purity gas delivery system with one-quarter inch male VCR connections. The flow rates of dielectric etch process feedstock gases are typically ≤ 3 standard liters per minute (slpm).

By installing purifier assemblies in the process gas lines directly prior to vacuum chamber entry (i.e., at the point-of-use), users can achieve the best protection for dry etch process control.

Pall Gaskleen SIP purification medium is also capable of removing gaseous contamination such as water and oxygen to less than 1 ppb levels from saturated feedstock gases.

In independent laboratory testing, the Gaskleen SIP purifier has demonstrated the ability to remove metal carbonyl (Fe(CO)₅, Ni(CO)₄) gaseous impurities to less than 1 ppb levels from carbon monoxide gas⁴.

The testing was performed using a Gas Chromatograph equipped with an Electron Capture Detector (GC-ECD). The testing apparatus consisted of cylinder sources of purified and metal carbonyl-laden CO, a customized gas sampling system, and precision mass flow controllers calibrated in carbon

monoxide prior to testing. GC-ECD instrument background levels fluctuated during the testing between 0.72 ppb to 12.24 ppb for Ni(CO)₄ impurity in the zero gas CO source. The test system schematic diagram is depicted in Figure 3; Figure 4 shows the Pall Gaskleen SIP purifier capacity curve for metal carbonyls.⁵

The graph in Figure 4 depicts removal efficiency over purifier lifetime. The purifier inlet challenge and effluent concentration levels are used to calculate the removal efficiency. For example, a removal efficiency of 99.99% translates to an effluent concentration of 10 ppb with a challenge of 100 ppm. The graph shows that the Gaskleen SIP purifier has a large capacity for metal carbonyls, removing gaseous impurities, such as Fe(CO)₅, Ni(CO)₄, to levels less than 1 ppb.

The Pall Gaskleen SIP purifier comprises an inorganic support and reactive alkali metal; both support and reactive alkali metal have an affinity for gaseous impurities. The AresKleen™ SIP medium's high surface area and reactivity provides for large capacity of metal carbonyls. In addition to metal carbonyl removal, the Gaskleen SIP purifier has demonstrated the ability to remove water, oxygen, and carbon dioxide gaseous impurities to sub-ppb levels in inert gas.⁶ Similar results are expected from the Gaskleen SIP purifier in CO gas service.

The control of gaseous contaminants is key to having reproducible dielectric etch results, and preventing yield and uniformity process upset occurrences. Pall Gaskleen SIP purifier assemblies are available in Top Mount and in-line configurations. (Refer to Pall Filtration Purifiers Datasheets for more details.)

References

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Gas Filtration Purifiers Data Sheet A79a
Mini-Gaskleen™ Purifier

Gas Filtration Purifiers Data Sheet A88
Gaskleen® II Purifier

Gas Filtration Purifiers Data Sheet A87a
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ABG-101-1104