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Invited

The Dry Etching of Oxides Using Anhydrous HF

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The etching of silicon dioxide layers through the use of a gaseous HF ambient at or near room temperature provides a technique to remove thin oxides with no substrate damage and no microcontamination added either in the form of particles or metallic ions. This technology has largely found use in the removal of native oxide layers formed intentionally or unintentionally during wafer processing. This paper will review the present state of knowledge of vapor phase HF etching.

Anhydrous HF etches silicon dioxide via the following reactions:

$$SiO_2(s) + 6HF(g) \overset{(H_2O)}{\rightleftharpoons} H_2SiF_6 + 2H_2O$$
$$H_2SiF_6 \rightleftharpoons SiF_4(g) + 2HF(g)^{1)}$$

where silicon tetrafluoride and water vapor are the final products of the reaction and both have high vapor pressures at room temperature allowing a gas phase etch to occur. This gas phase etch does not have the same surface tension-viscosity, and bubble formation limitations as does an aqueous HF etching solution and therefore is better able to penetrate small geometry high aspect ratio features that are formed by the advanced lithographic processes being employed today. This process does show great etch sensitivity to the moisture levels adsorbed on or inherent in the specific oxide to be etched. Ohmi2) has reported the existence of a critical HF concentration and moisture level below which no etching occurs. This is shown in Figure 1.

P. A. M. van der Heide et al1) and the present authors have shown that at elevated temperatures the etch rate decreases because of the depletion of water on the oxide surface. At sufficiently high temperatures (>50°C) the etch rate will tend toward zero. The application of a dry gas such as N_2 to the surface at room temperature will deplete the surface of water and will prevent etching from occurring. This can be utilized to accomplish an etch on one side of a wafer or the other.

The gas flow diagram of a system is shown in Figure 2. It is a single wafer etching system that uses a porous diffuser to achieve etch uniformities of 1% or less 3σ. The etch rate is controlled by the flow rate of Anhydrous HF and nitrogen as shown in Figure 3. Very low particle additions can be obtained by removing the native oxide by this process. Figure 4 shows these results.

B. E. Deal et al3) have etched silicon dioxide films at reduced pressure using HF/H_2O vapors from a heated bubbler and have reported etch rates of thermal oxides and particle data similar to that reported by these authors. A characteristic of the etch is that the metallic content of the surface is nearly the same before and after the vapor HF etch. This indicates that metals are not typically added during the process nor are they reduced.

The ability to selectively etch one oxide relative to another is a characteristic of this process. For certain oxides the etching can be absolutely selective, i.e., native oxide can be removed without any removal of the thermal oxide. Miki[4] has reported details of the room temperature critical concentration of HF and H_2O to etch various oxides. For some applications such as contact cleaning this selectivity may become a process problem. Detailed understanding of the critical concentration of HF and H_2O allows the selectivity to be tailored to the process through the turn on characteristics of the etch coupled with the actual etch rate difference between the exposed oxides[5]. This ability to adjust the characteristic concentration distinguishes this process from aqueous HF etching.

The anhydrous HF or vapor etching technology has been developed to serve single wafer applications. Because it is a "dry" process compared to aqueous HF etching it is compatible with single wafer cluster tool processing. This technology has the potential to integrate surface preparation with the process it serves, i. e., CVD/PVD, to allow the interface between the layers to be better controlled and more consistent.

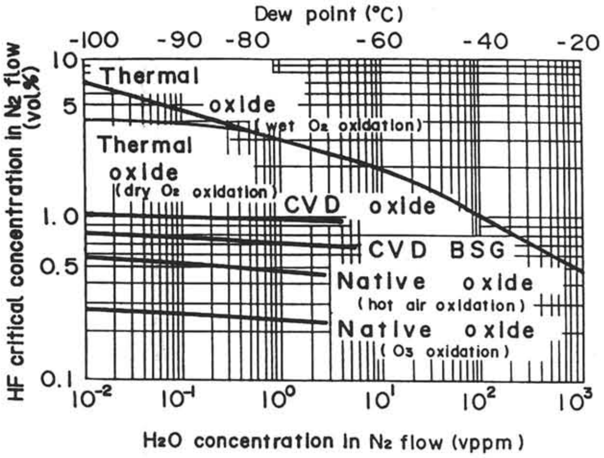

Fig. 1 Relationship of HF Critical Concentration and Moisture Level at Room Tempterature for Various Oxide Films. T. Ohmi et al

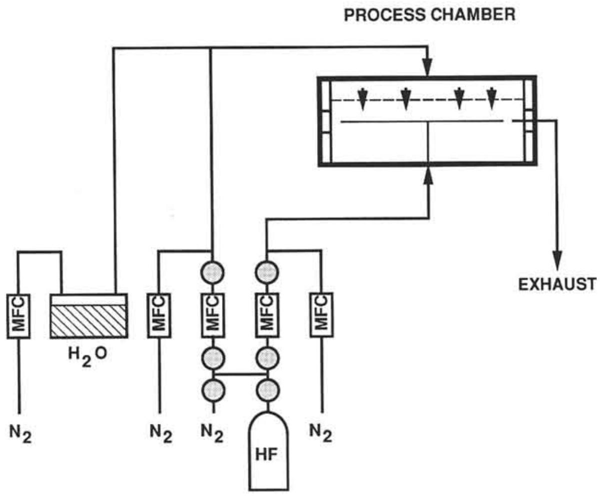

Fig. 2 System Gas Flow Diagram for Anhydrous HF Etching of Silicon Dioxide

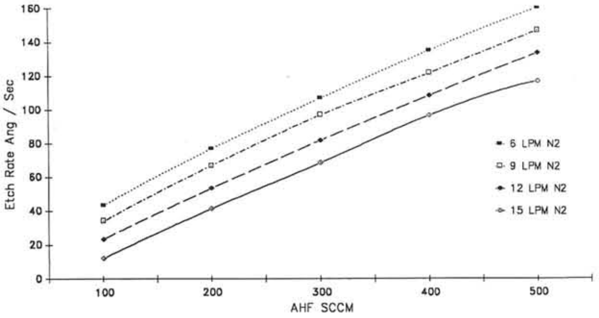

Fig. 3 Etch Rate /Sec vs Flow Rate of AHF and Nitrogen

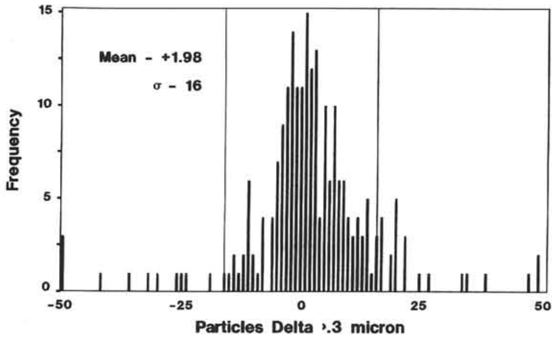

Fig. 4 Particle Performance of Native Oxide Etch

References

1) P. A. M. van der Heide, et al, J. Vac. Sci., Tech., A7, 1719 (1989).

2) T. Ohmi, et al; in Proceedings of the First International Symposium on Cleaning Technology in Semiconductor Device Manufacturing, Eds. J. Ruzyllo, R. Novak, The Electrochemical Society, 1989, p. 95.

3) B. E. Deal, et al; in Proceedings of the First International Symposium on Cleaning Technology in Semiconductor Device Manufacturing, Eds. J. Ruzyllo, R. Novak, The Electrochemical Society, 1989, p. 21.

4) N. Miki et al, Proceeding of the Int'l. Electron Devices Meeting (1988) pp 731-734.

5) M. Jenson, FSI Technical Report, June 1990.