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A New Chemical Dry Etching

Y. Horiike and M. Shibagaki

Toshiba Research and Development Center

Tokyo Shibaura Electric Co., Ltd., Kawasaki

Recently, the plasma technique with freon gases has been developed for etching of poly-Si, SiO_2 and Si_3N_4 films in IC fabrication processes.(1) This technique, however, has some drawbacks due to the immersion of the samples into the plasmas. In order to overcome the problems, we studied the construction of apparatus, and have developed a new method for chemical dry etching.

In this paper, we describe important features of this method and discuss the etching mechanisms involved.

Figure 1 shows the schematic of the experimental apparatus. The feature is a separation of a reaction region from a rf discharge region. The discharge region is constructed using an Al_2O_3 tube and a pair of perforated Al electrodes.

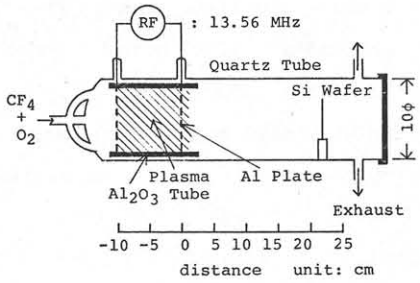

Fig. 1 Schematic of the experimental apparatus

Figure 2 shows the variation in the etch rate of poly-Si as a function of the distance from one of the electrodes. The rate decreases abruptly with increasing the distance under the condition of CF_4 discharge, while the rate becomes almost constant throughout the reaction vessel when O_2 is added to CF_4, in spite of the glow is completely disappeared in the vessel. These characteristics suggenst the formation of a highly excited species of a long lifetime by relatively high powered discharge of a CF_4-O_2 mixture.

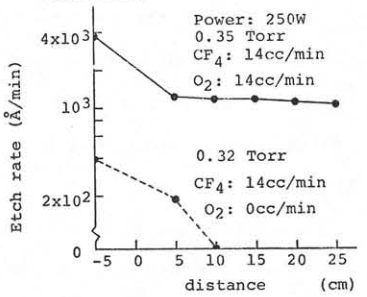

Fig. 2. Etchrate vs. a distance from the electrode

The etch rate for samples in the reaction vessel depends upon the ratio of the flow rate of O_2 to that of CF_4, q_{O_2}/q_{CF_4}. As seen in Fig. 3, the etch rate for poly-Si has a maximum at $q_{O_2}/q_{CF_4} \approx 1$. On the other hand, the rate for SiO_2 is much lower than for poly-Si and is almost constant along a wide range of this ratio.

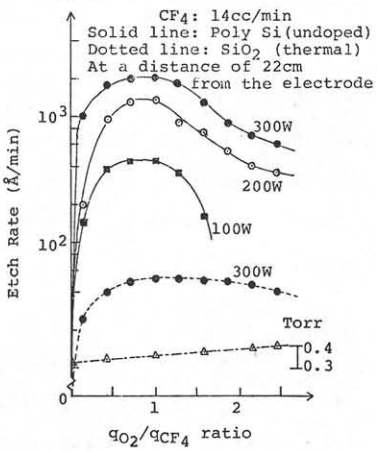

Fig. 3 Etch rate vs. q_{O_2}/q_{CF_4} for different rf inputs.

From an another experiment, it was found that the activation energies for etching reaction on

poly-Si and SiO_2 are 1.1 kcal/mol and 4.2 kcal/mol, respectively. This suggests that the etch rate of SiO_2 is limited by the reaction rate on the surface, whereas that of poly-Si is mainly determined by mass flow rate of the active species on the surface.

Gases in the vessel under etching conditions were measured using a Veeco GA-4 residual gas analyzer. Figure 4 shows the ion current variation as a function of q_{O_2}/q_{CF_4} for some typical mass ions. The ion current of mass number 47,66 (COF_2 fraction)[2] reaches a maximum when $q_{O_2}/q_{CF_4} \approx 1$. This tendency coincides well with the characteristic of the poly-Si etching shown in Fig. 3. Figure 5 indicates the relationship between the amount of COF_2 and area of poly-Si in the similar apparatus to Fig. 1. As already reported,[3] the rate decreases with increasing the area. Accordingly, the COF_2 is closely related to the reactive species.

Finally, the pressure dependence on the etch rate of poly-Si with a constant flow of the gases and a constant discharge condition were measured. The experiment showed that the rate is in proportion to p^2, as shown in Fig. 6.

From these experiments, it may be concluded that the reactive species in the new method differs from those in the conventional gas plasma processes. The advantages of this method are as follows: (i) Photoresists are not damaged during etching processes because the reaction vessel is maintained at room temperature, and so finer resolution is attained. (ii) The process does not cause any degradation of the electrical properties of IC's due to bombardment by charged particles.

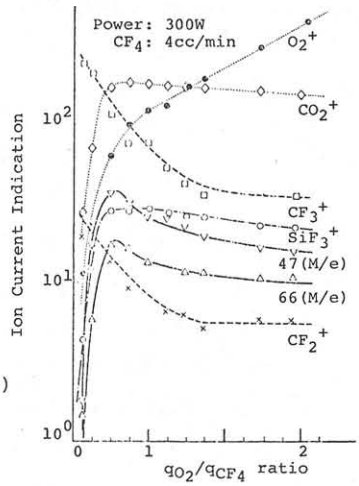

Fig. 4 Ion current vs. q_{O_2}/q_{CF_4} for some characteristic mass numbers.

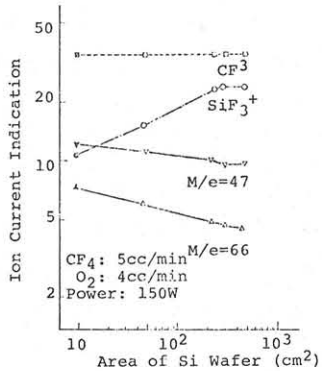

Fig. 5 Sample area vs. ion current of CF_3^+, SiF_3^+, M/e=47 and 66

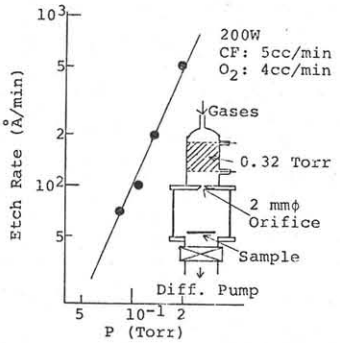

Fig. 6 Etch rate vs. pressure in the reaction vessel

Reference

(1) H. Abe, Proc. 4th C.S.S.D. 1974; Supplement J. Japan Society of Appl. Phys., 44, 287 (1975)

(2) A. Corm, et al, Compilation of Mass Spectral Data (Heyden Son Limited), 14-B 5-B, 23-B, (1966)

(3) Y. Mimura, The 7th Symposium on Semiconductors and Integrated Circuits Technology, Extend Abstracts, 73, Nov. (1974)