SiO2 Etching Characteristics of Perfluoro -2-butene (l-C4F8) and Hexafluoropropene (l-C3F6)

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ABSTRACTS

In dry etching processes, the perfluorocarbon compounds (PFCs) are commonly used as a reactant gas. In particular, in the etching of oxide and nitride, the use of a PFC seems to be unavoidable. As chip density rises, dry etching requires greater precision and selectivity. To achieve this, octafluorocyclobutane (c-C4F8) is widely used as an etching gas instead of conventional CF4, because the relatively high C/F ratio of C4F8 is believed to induce the formation of a C:F film on Si or SiN, which acts as an etching barrier, thus improving the selectivity. However, c-C4F8 is a PFC with a very high global-warming potential (GWP). So we have investigated perfluoro-2-butene (l-C4F8) and Hexafluoropropene (l-C3F6) as an alternative. The reduction of PFC emissions has become a major environmental issue in the development of semiconductor processes. It will be nearly impossible to replace current high-GWP PFCs if the alternatives do not provide good etching performance. This article is a study of the alternative gas, l-C4F8 and l-C3F6 gases, and for their etching characteristics. Table 1 shows the molecular structure and physical and chemical properies of c-C4F8, l-C4F8 and l-C3F6. l-C4F8 and l-C3F6 have a much lower GWP and a shorter life time than c-C4F8, but it is also somewhat toxic. Generally speaking, PFCs with a carbon double bond tend to have a low GWP and a short lifetime, and to be toxic. For the experiments, the dual frequency plasma reactor was used, where the operation pressure of 25mtorr, the frequency of top electrode power of 60MHz and bottom electrode power of 1.6MHz, and the wall temperature of 70℃ are employed. Figure 1 shows the schematic diagram of experimental apparatus in this study. The etch rate and profile of contact holes were obtained from SEM observations. Figure 2 shows the SEM images after the partial etching of contact hole using l-C4F8/O2/Ar and l-C3F6/ O2/Ar gas chemistries. The opening size of contact hole is 0.3um and the oxide film is a PE-TEOS oxide with 2um thickness. Photo resist (PR) selectivity to oxide of l-C3F6 is about 20% higher than that of l-C4F8. The oxide etch rate of contact hole of l-C4F8 is increased about 7% comparing with that of l-C3F6. l-C4F8 based recipe exhibits a reverse RIE lag that makes the etch rate the highest for 0.2um contact holes and lowest for open areas. Figure 3 shows the SEM images after 30% over etching of contact holes using l-C4F8-and l-C3F6-based recipes. The etched profile is almost same for both gas chemistries. The etching results about contact hole using l-C4F8- and l-C3F6- based recipes are summarized in table2. The contact-hole-patterned wafers with SiN and poly-Si were used for selectivity measurement. The nitride and poly silicon selectivity of l-C4F8- and l-C3F6- based recipes are higher than those of c-C4F8. High selectivity etching process (SAC) of both l-C4F8 and l-C3F6 was evaluated. The gaseous emissions were analyzed with a QMS and an FTIR.

These results show that the oxide etching characteristics of linear chain gases will be more useful than of c-C4F8 as device structures become smaller.

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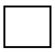
Gas	Name	Fomula	B.P.(℃)	GWP100/ lifetime	Toxic level
c-C4F8	octafluoro-cyclobutane		-5.7	9100/3200	non
l-C4F8	perfluoro-2-butene	CF3CF=CFCF3	1.3	<100 / <1	toxic
l-C3F6	hexafluoro-propene	CF3CF=CF2	-29	<100 / <1	LC50=750

Table 1. Molecular structure and properties of c-C4F8, l-C4F8 and l-C3F6

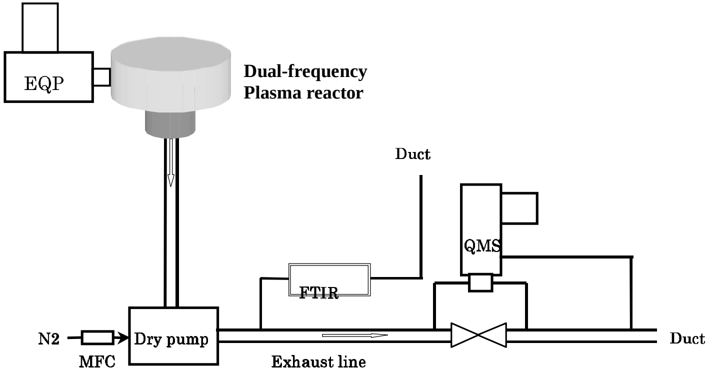


Fig.1. Schematic diagram of experimental apparatus

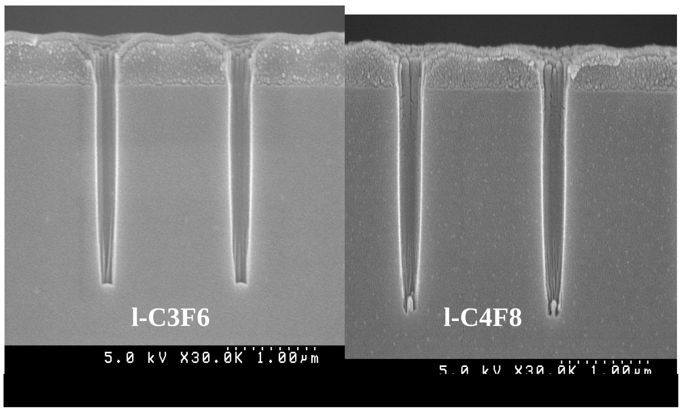


Fig.2. SEM images of contact holes after the partial etching with l-C3F6- and l-C4F8-based chemistries.

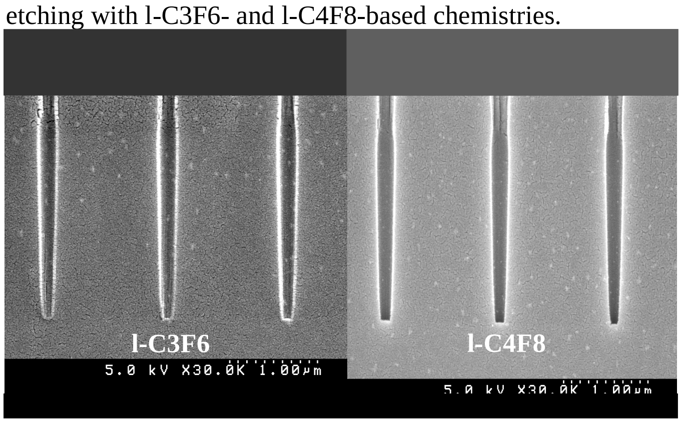


Fig.3. SEM images of contact holes after etching with l-C3F6-and l-C4F8-based chemistries.

	E/R (open area)	E/R (0.2μm)	SelPR (facet)	SelSiN	SelSi
c-C4F8	550nm/min	500nm/min	5.0	8.3	18.4
l-C4F8	563nm/min	576nm/min	5.07	13.7	26
l-C3F6	538nm/min	536nm/min	6.23	18.3	26

Table 2. Etch rate and selectivity for three prototype

recipes for contact hole etching.