Influence of Etch Gas on High Density Plasma Etching of Poly silicon Thin Films with Nanometer-Size Patterns

Young Soo Song and Chee Won Chung*

Department of Chemical Engineering and Institute of Clean Technology, Inha University,
253 Yonghyun-Dong, Nam-Ku, Incheon 402-751, Korea

High density plasma etching of polysilicon thin films with nanometer-size patterns was performed in an inductively coupled plasma. The etch process of polysilicon films with a photoresist mask was characterized using Cl₂, C₂F₆, and HBr gas chemistries in terms of etch rate, etch selectivity, and etch profile. The fast etch rate of polysilicon films was obtained in Cl₂/Ar gas and the high selectivity of polysilicon to photoresist was found in HBr/Ar gas mixture. The etching of polysilicon films masked by photoresist with nanometer-size patterns was attempted with various etch gases, and an anisotropic etching of 60 nm sized pattern was achieved in HBr/Ar and C₂F₆/Ar plasmas.

Results and Discussion

The etch rates and etch selectivities of polysilicon thin films using Cl₂/Ar, C₂F₆/Ar, and HBr/Ar gases are shown in Fig. 2. These etch rates were obtained at the etch condition containing coil power of 600 W, gas pressure of 5 mTorr, and 200 V dc bias to wafer susceptor. This etch condition was fixed as a standard etch condition through the entire etch experiment. The etch selectivities shown in Fig. 2b were calculated with the etch rates of polysilicon films and photoresists from Fig. 2a. As the concentration of Cl₂ gas increases, the etch rates of polysilicon and photoresist increase. In the C₂F₆ gas, the changes in the etch rates of polysilicon and photoresist with increasing C₂F₆ concentration show an identical trend. As the etch condition increases over 60% C₂F₆ gas, the etch rates of polysilicon and photoresist seem to be slightly decreased. This decrease is thought to be because the thin layer of polymer formed by C₂F₆ gas prevents both the polysilicon and photoresist from being etched.

Experimental

Polysilicon thin films were deposited on SiO₂/Si substrates by a low-pressure chemical vapor deposition (LPCVD) process. For etch rate and etch selectivity, the deposited polysilicon films were patterned by conventional photolithography and for the nanometer-size patterns on polysilicon films, an E-beam lithography was applied to define the patterns of 50-100 nm lines.

The etch equipment used in this study was a high density inductively coupled plasma reactive ion etch system (ICPRIE), which has an advanced cooling system to the wafer platen. Two rf power supplies at 13.56 MHz were applied to generate a high density plasma and to induce a self-bias voltage to the susceptor.

The etch rates were measured by a surface profiler and the etch profiles were observed by field-emission scanning electron microscopy (FESEM). In this study, chlorine, fluorine, and bromine gas chemistries were chosen for the etch characteristics of polysilicon thin films. The effect of etch gas on the etch rate, etch selectivity, and etch profile was investigated. Finally, nanometer-size etching of polysilicon thin films using a photoresist was carried out in Cl₂/Ar, C₂F₆/Ar, and HBr/Ar plasmas.

* Electrochemical Society Active Member.
E-mail: cwchung@inha.ac.kr
etched. As the concentration of HBr gas increases, the etch rate of polysilicon increases while that of photoresist decreases. As a result, the selectivity of polysilicon films to photoresist is greatly enhanced. The phenomenon of decreasing etch rate of photoresist with increasing concentration of HBr gas can be explained because the protection layer, which is formed from HBr gas, is more easily formed on the photoresist than on the polysilicon film. It is expected that this high selectivity plays a key role in etching for nanometer-size patterns of polysilicon thin films.

As shown in Fig. 2b, as the Cl2 concentration increases, the selectivity of polysilicon to photoresist gradually decreases. In the C2F6 gas, the selectivity of polysilicon films is almost constant. However, the selectivity of polysilicon increases with increasing HBr concentration because of the decrease in the etch rate of photoresist. Among the three etch gases, the fast etch rate of polysilicon film was found in a Cl2/Ar gas, and, at over 40% concentration of each gas, HBr/Ar and C2F6/Ar gases showed higher selectivity of polysilicon than Cl2/Ar gas.

To study the effect of etch gas on etch profile, the etching of polysilicon thin films with nanometer-size patterns was carried out. The mask patterns were formed by an E-beam lithography using polymethylmethacrylate (PMMA) and the pattern dimensions were in the range of 50-100 nm as a line. The concentration of each gas was fixed at 40%. Figure 3 shows the etch profiles of the polysilicon thin films with a 60 nm linewidth. Figure 3a is the profile of E-beam resist before the etching and the profile is well defined with an almost vertical wall. Figure 3b is the etch profile etched with Cl2/Ar gas. The sidewall angle of the etched pattern was shallow compared

Figure 2. (a) Etch rate of polysilicon thin films and (b) etch selectivity of polysilicon films to photoresist for Cl2/Ar, C2F6/Ar, and HBr/Ar gases.

Figure 3. Etch profiles of polysilicon thin films with 60 nm lines (a) before etching and after etching by (b) Cl2/Ar gas, (c) C2F6 gas, and (d) HBr/Ar gas.
to the etch profile before etching. This result shows the typical etch characteristic of Cl\textsubscript{2} gas, which erodes to the lateral direction as well as the vertical direction of the films. In the C\textsubscript{2}F\textsubscript{6}/Ar gas, the etch profile of polysilicon was enhanced, compared to that etched by Cl\textsubscript{2}/Ar gas. It is notable from Fig. 2b that the selectivity of polysilicon in C\textsubscript{2}F\textsubscript{6}/Ar gas is higher than that in Cl\textsubscript{2}/Ar gas. When HBr/Ar gas was used to etch the polysilicon films, an etch pattern with a high degree of anisotropy was obtained, which was almost comparable to the resist profile before etching.

From the three etch profiles of polysilicon films with nanometer-size patterns, it is evident that HBr/Ar and C\textsubscript{2}F\textsubscript{6}/Ar gases were more effective in achieving a good etch profile than Cl\textsubscript{2}/Ar gas. These results seem to be related with the selectivity of polysilicon to photoresist. Therefore, the etch chemistry is considered as a critical factor in etching of polysilicon films with nanometer-size patterns. A further study to examine the effect of etch parameters on the etch profile is needed for nanometer-size etching of polysilicon thin films.

Conclusions

Polysilicon thin films with nanometer-size patterns were etched in an ICP. Cl\textsubscript{2}, C\textsubscript{2}F\textsubscript{6}, and HBr gases were chosen and the influence of etch gases on the etch characteristics of polysilicon films were examined. Cl\textsubscript{2}/Ar gas showed a fast etch rate of polysilicon films and high selectivity of polysilicon to photoresist was obtained in HBr/Ar etch chemistry. Better etch profiles of polysilicon films with high fidelity were attained in HBr/Ar and C\textsubscript{2}F\textsubscript{6}/Ar etch gases than in Cl\textsubscript{2}/Ar gas. The high selectivity of polysilicon to photoresist resulted in good etch profiles. 60 nm size patterns on polysilicon thin films were successfully etched using HBr/Ar and C\textsubscript{2}F\textsubscript{6}/Ar etch gases.

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