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NO と F_2 を用いた Si ケミカルドライエッチング中の F 失活過程の解析（I）

Analysis of F loss during the chemical dry etching of Si using NO and F_2 gases (I)

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【Introduction】 Maintaining the F density during the chemical dry etching of Si using the reaction of F_2 + NO → F + FNO is critical to keep the high etch rate and the etch uniformity across the large-scale wafer. However, F is lost by the reaction of F + NO → FNO in the gas phase [1] and by the reaction at the Si surface [2]. In order to apply this chemical dry etching method to the large-scale Si wafer fabrication; i.e., selectively etch Si over SiO_2, removing sacrificial layer of the microelectromechanical systems (MEMS), texturing the Si surface for the solar panel application to improve the light-electricity conversion efficiency, eliminating the plasma-induced damage layer after the gate etching process, and removing the damaged layer after the chemical mechanical polishing (CMP); the optimal chamber design and the process conditions must be considered to minimize the F loss between the gas mixing point and the surface of materials to be processed. In this study, we have been evaluating the main cause of F loss by designing the gas mixing room, the gas outlet, and by optimizing the process parameters.

【Experimental】 10 mm x 100 mm Si samples consisting of SiO_2 mask with square and line patterns were cleaved from the Si (100) wafer. Ar/NO/10%F_2 at the total flow rate of 107 sccm was introduced in the process chamber while varying the chamber pressure, P, between 100 ~ 1000 Pa, and the distance of gas outlet and the sample, d, from 30 to 70 mm during the process time of 5 min. The vertical etch rate, E_V, and the lateral etch rate, E_L, of Si and SiO_2 were measured from the cross-section of the cleaved sample by scanning electron microscopy (SEM). The mean free path, λ, and the number of collisions, n, between the gas mixing point and the sample surface were calculated based on the P and d. The relationship between the E_V, E_L, and n were studied to elucidate the effect of F loss due to collision in the gas phase and the reaction at the Si surface.

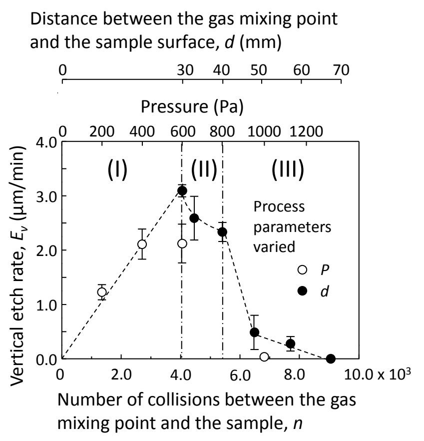

Fig. 1 Relationship between the vertical etch rate, E_v, and the number of collisions between the gas mixing point and the sample, n. Two experimental parameters were varied, one was the pressure, P, and the other was the distance between the sample and the mixing point, d.

【Results and Discussion】 Figure 1 shows the relationship between the E_V and n calculated from P and d. E_v increased linearly proportional to the n up to ~ 4000 (Region (I)). Then the E_V gradually decreased at $4000 < n < 5500$ by the function of $\sim 1/d^2$ (Region (II)). When $n > 5500$, the significant drop of E_V was observed (Region (III)) with the increase of P and d. Preliminary, we have been considering that the F generation is increased by the reaction of F_2 + NO → F + FNO (Region (I)) but as the n increased, the F is lost at the gas phase by the reaction of F + NO → FNO (Region (II)). The further increase of n leads to the complete loss of F in the gas phase as well as the encapsulation of adsorption site at the Si surface with NO and FNO (Region (III)).

【References】 [1] Hoell et al. J. Chem. Phys. **58** (1973) 2896. [2] Tajima *et al*. J. Phys. Chem. C **117** (2013) 20810.

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